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Rockport Reservoir and Echo Reservoir Total Maximum Daily Loads

Final Report

Prepared for

Utah Department of Environmental Quality, Division of Water Quality

Prepared by

SWCA Environmental Consultants

EPA Approval Date: September 16, 2014

Utah Department of Environmental Quality
Division of Water Quality

Rockport Reservoir TMDL

EPA Approval Date: September 16, 2014

Waterbody ID	UT-L-16020101-002_00
Location	Summit County, Utah
Pollutants of Concern	Total nitrogen (TN) Total phosphorus (TP)
Designated Beneficial Uses	Domestic water use (1C) Primary contact recreation (2A) Secondary contact recreation (2B) Cold water game fish (3A) Agricultural water supply (4)
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain
Current Load	2,337 kg TP/summer season (April – September) 3,359 kg TP/year 18,573 kg TN/summer season (April – September) 27,642 kg TN/year
Loading Capacity (TMDL)	1,519 kg TP/summer season (8.3 kg TP/day) (April – September) 2,541 kg TP/year 12,072 kg TN/summer season (66.3 kg TN/day) (April – September) 21,141 kg TN/year
Defined Targets/Endpoints	Nutrients - In-reservoir mean seasonal (May 15 - September 30) TP of 0.014 mg/L - In-reservoir mean seasonal (May 15 - September 30) TN of 0.26 mg/L Trophic Status and Algae - In-reservoir mean seasonal (May 15 - September 30) chlorophyll *a* of 3.5 µg/L - Algal dominance other than blue-green species - Mesotrophic state Dissolved Oxygen (DO) - Mixed reservoir periods: 4.0 mg/L DO throughout at least 50% of the water column; 5.0 mg/L DO at surface on average over 7-day period; 6.5 mg/L DO at surface on average for 30-day period - Stratified reservoir periods: Metalimnion layer (at least 2-m) throughout the reservoir in which DO is maintained above 4 mg/L and temperature is below 20°C; 5.0 mg/L DO at surface on average over 7-day period; 6.5 mg/L DO at surface on average for 30-day period

Waste Load Allocation	495 kg TP/summer season (2.8 kg TP/day) (April - September) 990 kg TP/year 4,504 kg TN/summer season (24.7 kg TN/day) (April - September) 9,008 kg TN/year
Future Waste Load Allocation	72 kg TP/summer season (0.4 kg TP/day) (April - September) 456 kg TP/year 716 kg TN/summer season (3.9 kg TN/day) (April - September) 4,525 kg TN/year
Nonpoint Source Waste Load Allocation	952 kg TP/summer season (5.2 kg TP/day) (April - September) 1,095 kg TP/year 6,853 kg TN/summer season (37.7 kg TN/day) (April - September) 7,608 kg TN/year
Margin of Safety	Implicit
Regulated Point Sources	Kamas Wastewater Treatment Plant (UPDES UT0020966) Oakley Wastewater Treatment Plant (UPDES UT0020061) UDWR Fish Hatchery near Kamas (General permit) Francis Wastewater Treatment Plant (UPDES UTOP00202)
Watershed Nonpoint Sources	Agricultural land uses (grazing, fertilizer, and irrigation) Urban stormwater Septic systems discharges Landfill seepage Natural background sources, including phosphatic shales

Utah Department of Environmental Quality
Division of Water Quality

Echo Reservoir TMDL

EPA Approval Date: September 16, 2014

Waterbody ID	UT-L-16020101-001_00
Location	Summit County, Utah
Pollutants of Concern	Total nitrogen (TN) Total phosphorus (TP)
Designated Beneficial Uses	Domestic water use (1C) Primary contact recreation (2A) Secondary contact recreation (2B) Cold water game fish (3A) Agricultural water supply (4)
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain
Current Load	5,387 kg TP/summer season (April – September) 9,288 kg TP/year 42,709 kg TN/summer season (April – September) 76,660 kg TN/year
Loading Capacity (TMDL)	3,502 kg TP/summer season (19.2 kg TP/day) (April – September) 7,403 kg TP/year 27,761 kg TN/summer season (152.5 kg TN/day) (April – September) 61,712 kg TN/year
Defined Targets/Endpoints	Nutrients - In-reservoir mean seasonal TP of 0.018 mg/L - In-reservoir mean seasonal TN of 0.27 mg/L Trophic Status and Algae - In-reservoir mean seasonal chlorophyll *a* of 3.5 µg/L - Algal dominance other than blue-green species - Mesotrophic state Dissolved Oxygen (DO) - Mixed reservoir periods: 4.0 mg/L DO throughout at least 50% of the water column; 5.0 mg/L DO at surface on average over 7-day period; 6.5 mg/L DO at surface on average for 30-day period - Stratified reservoir periods: Metalimnion layer (at least 2-m) throughout the reservoir in which DO is maintained above 4 mg/L and temperature is below 20°C; 5.0 mg/L DO at surface on average over 7-day period; 6.5 mg/L DO at surface on average for 30-day period

Current Waste Load Allocation	1,237 kg TP/summer season (6.8 kg TP/day) (April – September) 2,473 kg TP/year 12,238 kg TN/summer season (67.2 kg TN/day) (April – September) 24,440 kg TN/year
Future Waste Load Allocation	485 kg TP/summer season (2.7 kg TP/day) (April – September) 1,455 kg TP/year 4,918 kg TN/summer season (27 kg TN/day) (April – September) 14,755 kg TN/year
Nonpoint Source Load Allocation	1,779 kg TP/summer season (9.8 kg TP/day) (April – September) 3,474 kg TP/year 10,605 kg TN/summer season (58.3 kg TN/day) (April – September) 22,517 kg TN/year
Margin of Safety	Implicit
Regulated Point Sources	Coalville Wastewater Treatment Plant (UPDES UT0021288) Silver Creek Water Reclamation Facility (UPDES UT0024414) Blue Sky Resort Wastewater Treatment Plant (UPDES UT0025763) Park City Tunnels (UPDES UT0025941; UPDES UT0025925)
Watershed Nonpoint Sources	Agricultural land uses (grazing, fertilizer, and irrigation) Urban stormwater Septic systems discharges Channel erosion Natural background sources including phosphatic shales Releases from Rockport Reservoir

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ROCKPORT RESERVOIR
AND ECHO RESERVOIR
TOTAL MAXIMUM DAILY LOADS

FINAL REPORT

Prepared for

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ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
ac-ft	acre-feet or acre-foot
BLM	Bureau of Land Management
BMP	best management practices
BOD	biochemical oxygen demand
BOR	Bureau of Reclamation
cfs	cubic feet per second
CWA	Clean Water Act
DO	dissolved oxygen
DWQ	Division of Water Quality
DWR	Division of Wildlife Resources
EPA	Environmental Protection Agency
GOMB	Governor's Office of Management and Budget
kg	kilogram
m	meters
MGD	million gallons per day
mg/L	milligrams per liter
MOD	metalimnetic oxygen depletion
MOS	margin of safety
NRCS	Natural Resources Conservation Service
NTUs	nephelometric turbidity units
SWAT	Soil and Water Assessment Tool
SWCA	SWCA Environmental Consultants
TKN	total Kjeldhal nitrogen
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
UDEQ	Utah Department of Environmental Quality
UPDES	Utah Pollutant Discharge Elimination System
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WLA	waste load allocations
WRCC	Western Regional Climate Center
WRF	water reclamation facility
WWTP	wastewater treatment plant

1. INTRODUCTION

1.1. Purpose

This document presents the total maximum daily loads (TMDL) study for the impaired waters of Rockport and Echo Reservoirs in the Weber River watershed (UT16020102-022) in fulfillment of requirements of the Clean Water Act (CWA).

A TMDL study determines the amount of an identified pollutant (i.e., the load) that a waterbody can receive while preserving its designated uses and state water quality standards. Once the pollutant loads have been identified, controls are implemented to reduce those loads until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL study, it is submitted to the Utah Water Quality Board and U.S. Environmental Protection Agency (EPA) for approval.

The Federal Water Pollution Control Act is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was expanded in 1972 and became known as the Clean Water Act. The purpose of the CWA is to improve and protect the physical, chemical, and biological integrity of the nation's waters. The CWA requires EPA or delegated authorities such as states, tribes, and territories to evaluate the quality of waters, establish beneficial uses, and define water quality criteria to protect those uses. Section 303(d) of the CWA requires that each state submit a list of waterbodies that fail state water quality standards to the EPA every 2 years. This list is the "303(d) list," and waterbodies identified on the list are referred to as "impaired waters." For impaired waters, the CWA requires a TMDL study for each pollutant responsible for impairment of its designated use(s).

The Utah Department of Environmental Quality (UDEQ), Division of Water Quality (DWQ) collects biological and water quality data to assess its waters according to its designated beneficial uses and water quality standards (Utah State Administrative Code R317). Based on this assessment, Echo Reservoir was included on the State of Utah's 303(d) list in1996, and Rockport Reservoir was included in 2008.

1.2. Problem Statement

Rockport and Echo Reservoirs are listed as impaired due to violations of the cold-water fishery dissolved oxygen (DO) standards. Echo Reservoir was first listed in 1996 whereas Rockport Reservoir was first listed in 2008. Impairment occurs in the bottom layer (the hypolimnion) of the reservoirs, which does not mix with surface waters during the summer due to thermal stratification (Figure 1.1). Over the course of the summer, oxygen is depleted in this lower layer while surface temperatures become too warm for cold-water species of fish.-Rockport and Echo Reservoirs are also listed as impaired for exceedance of the temperature standard for cold-water fishery. DWQ is addressing this impairment in a separate document.

DO is important to the health and viability of the cold-water fishery. Concentrations of 6.0–8.0 milligrams per liter (mg/L) are necessary for the health and viability of fish and other aquatic life. Low DO concentrations (less than 4.0 mg/L) cause stress to fish species, promote disease, and ultimately result in stunted growth and/or death.

Low DO in the reservoirs is due in part to the decomposition of algae and other organic matter in the hypolimnion. Algal growth is fueled by excess nutrient loads of nitrogen and phosphorus to the reservoir. When algae die and settle to the bottom, decomposition of the dead algae and other detritus (nonliving organic matter) consumes the oxygen supply in the water. Reservoirs are especially sensitive to excess nutrient loads due to their high surface area to volume ratio and use as water storage facilities.

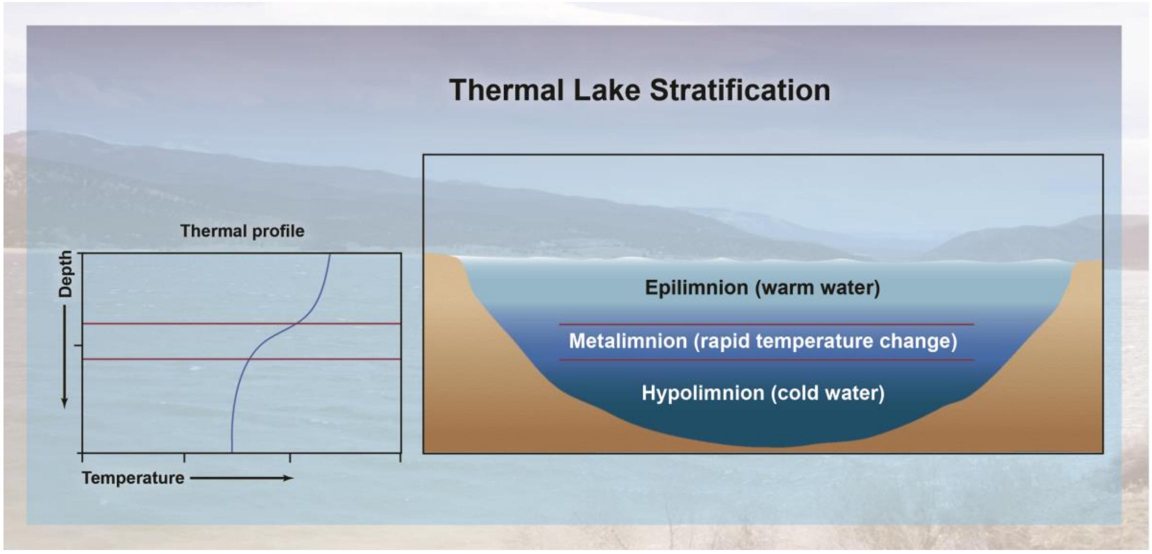

Figure 1.1. Profile view of thermal stratification in a typical lake or reservoir.

The shapes and settings of Rockport and Echo Reservoirs also contribute to low DO during summer months. Notably, the water levels at the inlet of each reservoir are shallow, whereas the water levels just upstream of the outlet are deep and the reservoir shape is long and narrow. As a result, the surface area of the reservoirs in the late-spring and early summer is quite large compared to the relatively small volume of hypolimnetic water near the outlet (i.e., the dam segment of reservoirs; Figure 1.2). As the reservoirs are drawn down, this small pool of hypolimnetic water ultimately receives all of the algal organic matter, and its associated oxygen demand, produced in the early spring and summer. The result of this phenomenon is that even at very low nutrient and algal concentrations, the hypolimnia of Rockport Reservoir and Echo Reservoir become depleted of oxygen over the course of the summer season.

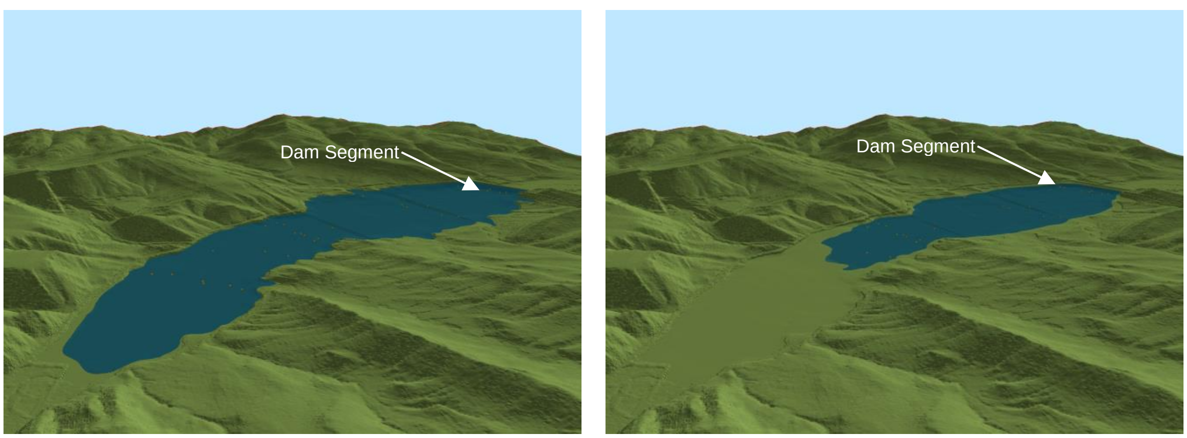

Figure 1.2. Change in Rockport Reservoir water level in 2007 from May 15 to September 30.

1.3. Regional Setting

The watersheds draining to Rockport Reservoir and Echo Reservoir are used as the study watershed in the TMDL (Figure 1.3). Watershed characteristics are described separately for the Rockport Reservoir watershed and the Echo Reservoir watershed. The Echo Reservoir watershed characteristics do not included the Rockport Reservoir watershed because Rockport Reservoir serves as a reset point in the system.

1.3.1. History

Rockport and Echo Reservoirs are two of the seven reservoirs built by the Bureau of Reclamation (BOR) as part of the Weber River Project to store water and supply it to the northern Wasatch Front (Figure 1.3). Rockport Reservoir, located 1.5 miles south of Wanship, Utah, is contained by Wanship Dam, an earth-filled dam that was completed in 1957. When full, Rockport Reservoir maintains a surface elevation of 6,049 feet with a 62,100-acre-foot (ac-ft) storage capacity. The normal operating depth of the reservoir is 150 feet. The dam outlet has a capacity to release 1,000 cubic feet per second (cfs), and the spillway has the capacity to release 10,800 cfs.

Echo Reservoir is contained by Echo Dam, an earth-filled dam that was completed in 1931; it is located 6 miles north of Coalville, Utah. When full, Echo Reservoir maintains a surface elevation of 5,560 feet with an approximately 74,000-ac-ft storage capacity (Department of the Interior 2009). The normal operating depth of the reservoir is 110 feet. The dam outlet has a capacity to release 2,100 cfs, and the spillway has the capacity to release 15,000 cfs.

Water resources in the Weber River watershed are well developed. It is estimated that water deliveries for municipal and agricultural needs make up 30% and 70% of use, respectively. In addition, Rockport Reservoir hosts a popular state park, and both reservoirs are used for recreational activities, including fishing and boating.

In the 1850s, Mormon Pioneers settled in the Weber River Basin, bounded by the Uinta Mountains to the east and the Wasatch Range to the west. Mountain-fed streams supported irrigation for small communities. In the 1860s, wagons moved coal from Coalville down to the Salt Lake Valley. In 1873, the Utah Eastern Railroad built a line from Coalville to what is now the current location of Echo Reservoir. This line eventually became part of the Union Pacific Railroad. Discovery of lucrative metals such as lead, silver, and zinc resulted in mining and further expansion. Economic opportunity led to development of canals and eventually storage reservoirs capable of supporting the accompanying population growth (Utah State Historical Society 1988).

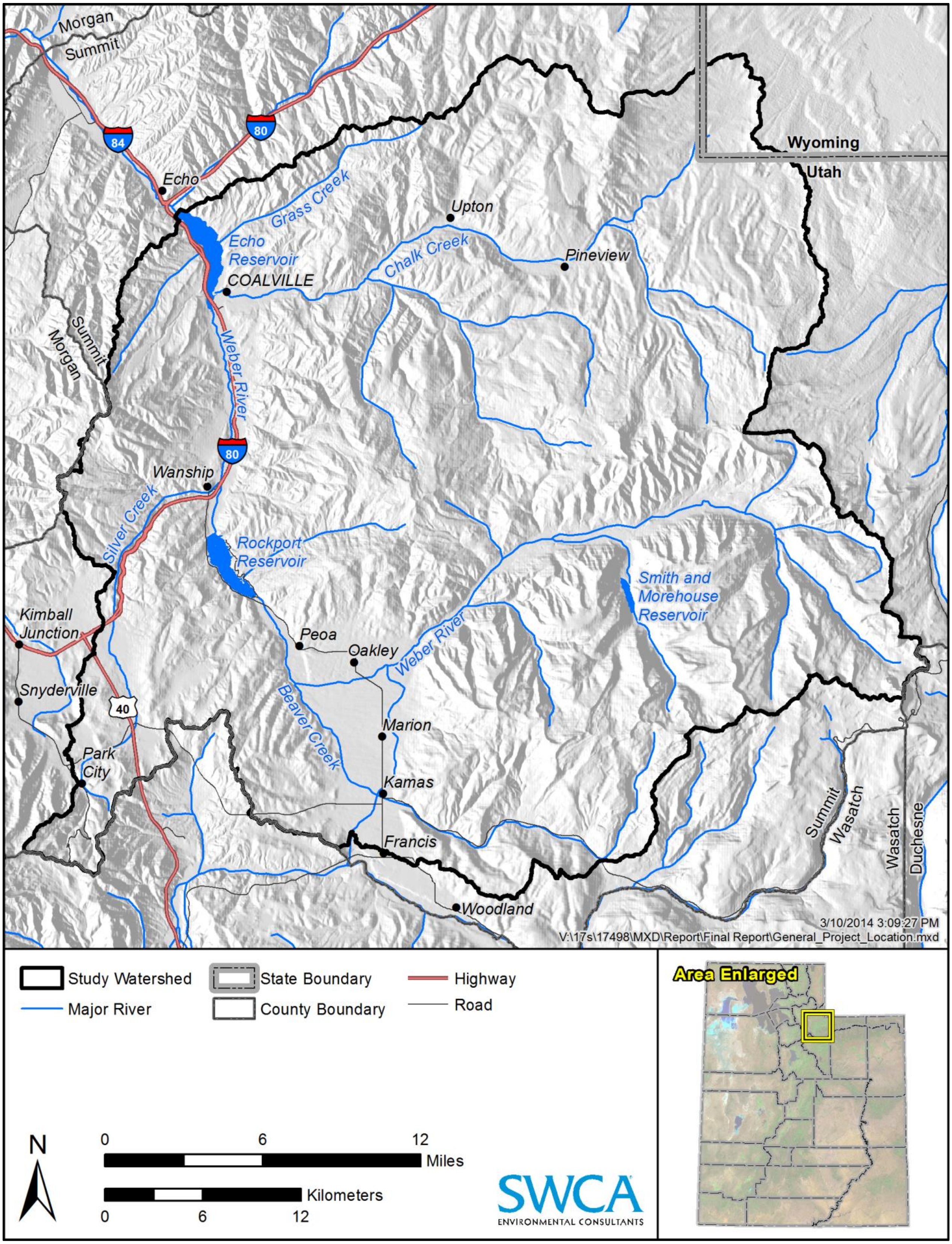

Figure 1.3. Map of study watershed (the Echo Reservoir and Rockport Reservoir watersheds), including state and county boundaries.

1.3.2. Population and Growth

Echo and Rockport Reservoirs are impoundments of the Weber River in the Upper Weber watershed. The watershed covers approximately 464,000 acres, most (99%) of which is in Summit County, Utah. The remaining watershed area covers parts of Duchesne County, Utah; Morgan County, Utah; Wasatch County, Utah; and Uinta County, Wyoming. For this reason, most of the population using the water (an estimated 36,324 individuals in 2010) is found in Summit County, Utah. Summit County is made up of seven primary municipalities; their 2000 and 2010 populations are shown in Table 1.1. As of May 2012, the county had 13,103 non-primary residential structures versus 12,613 primary residential structures. These include cabins, condominiums, and mobile homes, as well as the standard home; these do not include commercial, vacant land, or exempt properties. The county as a whole is projected to grow by 56% by 2030, compared to a 42% projected growth for the entire State of Utah. Much of this growth is projected for small towns and rural areas in the county.

Table 1.1. Population of Weber River Watershed and Surrounding Areas

Area	Population 2000[1]	Population 2010[1]	Population 2030[2]
State of Utah	2,223,169	2,763,885	3,913,605
Summit County	29,736	36,324	56,890
Coalville City	1,382	1,363	1,859
Francis Town	698	1,077	2,415
Henefer Town	684	766	1,212
Kamas City	1,274	1,811	2,864
Oakley City	948	1,470	3,297
Park City	7,371	7,547	11,444
Balance of Summit County	17,374	22,290	33,799

[1] Data from Economic Report to the Governor (State of Utah 2011).

[2] Data from Governor's Office of Management & Budget (State of Utah 2012)

1.3.3. Socioeconomics

The economic base of the study watershed in Summit County is varied. The top three employment sectors in Summit County from 2007 to 2011 were arts, entertainment, accommodation and food services (18.6%); education, health, and social services (15%); and professional and administrative services (13.3%). The median and mean household incomes for Summit County are $84,752 and $112,646, respectively. Unemployment between 2007 and 2011 was estimated to be 4.9% (U.S. Census Bureau 2011).

Agriculture, forestry, fisheries, hunting, and mining represent 1.6% of industry in Summit County (U.S. Census Bureau 2011). The number of farms in Summit County increased from 557 in 2002 to 629 in 2007 with the average market value per farm production up 15% to $40,415 over this same time period. In 2007, livestock sales represented 94% of the total market value of agricultural production in Summit County (National Agricultural Statistics Service 2007).

1.3.4. Climate

Three active climate stations in the study watershed were used for the TMDL analysis. Climate data available for these three stations were obtained from the Western Regional Climate Center (WRCC 2012). Table 1.2 lists the climate station names and identification numbers, station locations, elevations, and data periods of record.

Table 1.2. Active Climate Stations in the Study Watershed

Station Name (Identification Number)	Location	Elevation	Period of Record
Kamas (424467)	40°39'N, 111°17'W	6,510 feet	1948–2011
Wanship Dam (429165)	40°48'N, 111°24'W	5,910 feet	1955–2012
Coalville (421590)	40°56'N, 111°10'W	6,420 feet	1974–2011

Figure 1.4 shows variation in average monthly precipitation for the three active climate stations in the study watershed. Tables 1.3, 1.4, and 1.5 show the monthly climate summaries for each of the three stations. The Kamas station (424467) represents climatic conditions in the upper reaches of the study watershed. The Wanship Dam (429165) and Coalville (421590) stations represent climate conditions at Rockport Reservoir and Echo Reservoir, respectively.

Average monthly high and low temperatures at these stations range from approximately 8 degrees Fahrenheit (°F) in January to 86°F in August. Average minimum temperatures at these stations are below freezing from October to May. Average annual precipitation is approximately 15–17 inches, with the greatest monthly precipitation averages occurring in April, May, and October.

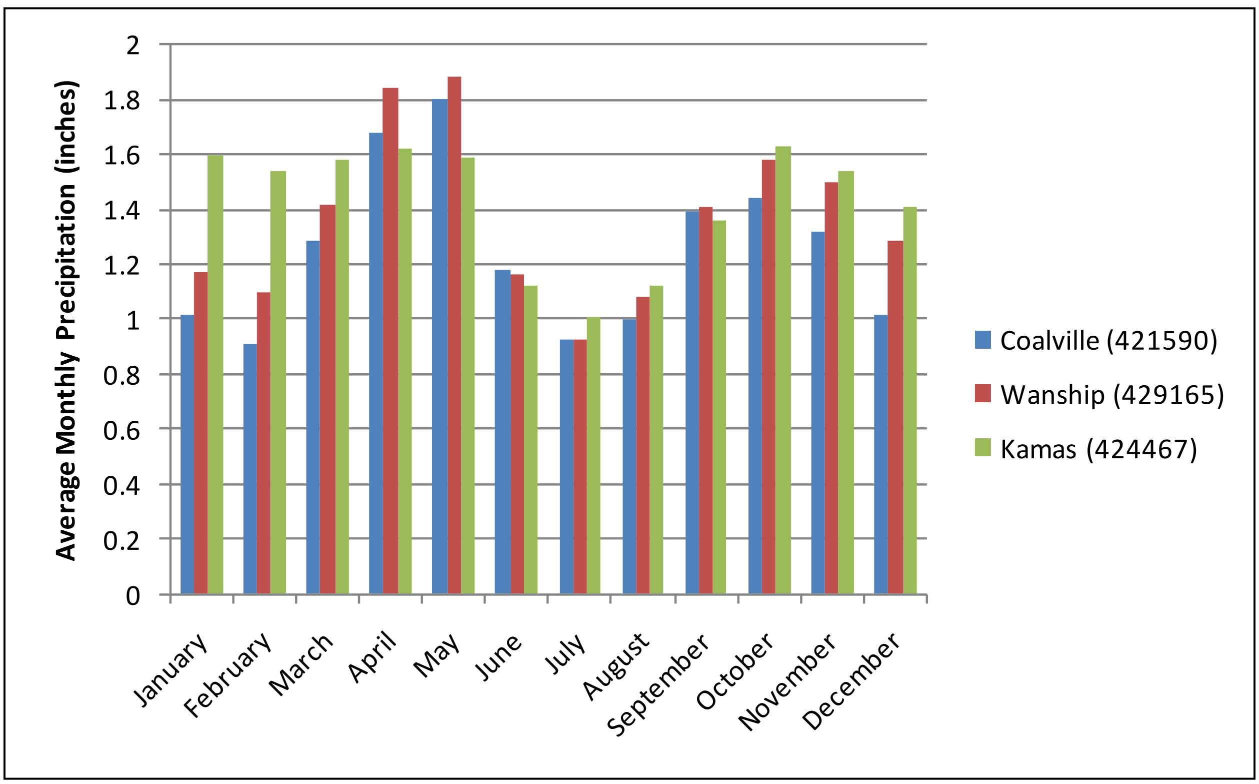

Figure 1.4. Average monthly precipitation at three climate stations in the study watershed.

Table 1.3. Monthly Climate Summary for Kamas Station (424467)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average maximum temperature (°F)	36.0	39.8	46.5	55.6	66.1	76.0	85.3	83.5	74.7	62.0	46.1	37.3	**59.1**
Average minimum temperature (°F)	12.2	14.7	21.7	27.8	35.0	41.0	48.0	46.6	38.6	30.0	21.1	13.3	**29.2**
Average total precipitation (inches)	1.60	1.54	1.58	1.62	1.59	1.12	1.01	1.12	1.36	1.63	1.54	1.41	**17.12**
Average total snowfall (inches)	20.1	15.6	10.7	6.5	2.2	0.2	0	0	0.5	2.5	12.6	18.7	**89.5**
Average snow depth (inches)	9	10	3	0	0	0	0	0	0	0	1	5	**2**

Source: Kamas station (424467) from 10/1/1948 to 12/31/2011 (WRCC 2012)

Table 1.4. Monthly Climate Summary for Wanship Dam Station (429165)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average maximum temperature (°F)	36.2	40.1	48.0	57.6	68.2	78.3	86.6	85.3	76.0	63.6	47.3	37.5	**60.4**
Average minimum temperature (°F)	11.7	14.8	21.9	28.5	35.3	41.3	47.2	45.7	37.4	28.9	20.9	13.5	**28.9**
Average total precipitation (inches)	1.17	1.10	1.42	1.84	1.88	1.16	0.93	1.08	1.41	1.58	1.50	1.29	**16.36**
Average total snowfall (inches)	15.2	13.9	10.7	6.4	0.9	0.1	0	0	0.3	1.9	10.2	13.9	**73.4**
Average snow depth (inches)	5	4	1	0	0	0	0	0	0	0	1	2	**1**

Source: Wanship Dam station (429165) from 8/1/1955 to 1/31/2012 (WRCC 2012)

Table 1.5. Monthly Climate Summary for Coalville Station (421590)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average maximum temperature (°F)	35.8	39.0	44.7	53.7	62.9	73.7	82.8	80.4	72.0	60.4	45.8	36.9	**57.3**
Average minimum temperature (°F)	8.5	9.7	18.3	25.9	32.8	38.3	45.0	43.0	35.4	26.6	16.6	9.6	**25.8**
Average total precipitation (inches)	1.02	0.91	1.29	1.68	1.80	1.18	0.93	1.00	1.39	1.44	1.32	1.02	**14.98**
Average total snowfall (inches)	16.6	13.9	13.4	7.0	3.1	0.3	0	0	0.6	3.1	11.4	15.3	**84.7**
Average snow depth (inches)	8	9	5	1	0	0	0	0	0	0	2	6	**3**

Source: Coalville station (421590) from 10/11/1974 to 11/30/2011 (WRCC 2012)

2. WATER QUALITY CONCERNS

2.1. Beneficial Uses and Impaired Waters

The purpose of the CWA is to improve and protect water quality through the restoration and maintenance of the physical, chemical, and biological integrity of the nation's waters. Protection of waters under the CWA consists of three main components: designating beneficial uses, establishing water quality criteria to protect those uses, and implementing anti-degradation policies and procedures.

Under Section 303(d) of the CWA, each state must submit a list to the EPA identifying waters that are not achieving water quality standards despite the application of technology-based controls in Utah Pollutant Discharge Elimination System (UPDES) permits. The waters identified on the 303(d) list are known as impaired waters.

The State of Utah designates beneficial uses to all surface waters in the state according to the classes outlined in Table 2.1. Recreational classifications are for waterbodies that are suitable, or are intended to be made suitable, for frequent and infrequent contact recreation.

Table 2.1. Summary of Use Designations for Rockport and Echo Reservoirs

Class	Designated Beneficial Use
1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water
2A	Protected for frequent contact recreation such as swimming
3A	Protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain
4	Protected for agricultural uses including irrigation of crops and stock watering

Source: Utah Administrative Code R317-2

The State of Utah has designated the beneficial uses for Rockport and Echo Reservoirs to be domestic water use (1C), frequent contact recreation (2A), cold-water game fish and the associated food chain (3A), and agricultural water supply (4). Rockport Reservoir was first listed on the State of Utah's 2008 303(d) list as impaired due to low DO and excess total phosphorus (TP) loading. Echo Reservoir was first listed on the State of Utah's 1996 303(d) list as impaired due to low DO and to pH measurements that exceeded state criteria; however, pH was removed from the list in 2003 and TP was added. Both reservoirs are currently listed as impaired due to violations of the cold-water fishery (3A) DO standards. Assessment of these uses and the level of support are discussed below.

2.2. Water Quality Standards Applicable to Rockport Reservoir and Echo Reservoir

Water quality criteria specific to designated beneficial uses consist of numeric limits for individual pollutants as well as narrative descriptions of desired conditions. Water quality standards applicable to the uses designated for Rockport and Echo Reservoirs are summarized in Table 2.2. The most applicable water quality standards for this TMDL are the standards associated with DO. Cold-water sport fish species are not known to reproduce in the reservoir; therefore, the early life-stage criteria do not apply.

The state DO criteria for all life stages of cold-water fish are 4.0 mg/L as a 1-day minimum, 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average.

Table 2.2. Selected Water Quality Criteria for Designated Uses in Rockport and Echo Reservoirs

Parameter	Class 1C	Class 2B	Class 3A
Physical			
pH (range)	6.5–9.0	6.5–9.0	6.5–9.0
Turbidity increase (NTU)	N/A	10	10
Temperature (ºC)	N/A	N/A	20
Maximum temperature change (ºC)	N/A	N/A	2
DO[1]			
30-day average	N/A	N/A	6.5
7-day average	N/A	N/A	9.5/5.0
1-day minimum	N/A	N/A	8.0/4.0
Total dissolved gases (% saturation)	N/A	N/A	<110%
Inorganics (maximum)			
Nitrate as N (mg/L)	10	N/A	N/A
Total ammonia as N (mg/L)	See footnotes below		
Pollution Indicators[4]			
Biochemical oxygen demand (BOD) (mg/L)	N/A	5	5
Nitrate as N (mg/L)	N/A	4	4
Total phosphorus as P (mg/L)	N/A	0.025	0.025

Notes: NTU = nephelometric turbidity units*;* ºC = degrees Celsius

[1] These limits are not applicable to lower water levels in deep impoundments. First number in column details when early life stages are present; second number details when all other life stages are present.

[2] The 30-day average concentration of total ammonia nitrogen (in mg/L as N) does not exceed, more than once every 3 years on the average, the chronic criterion calculated using the following equations:

Fish Early Life Stages are Present:

mg/Las N (Chronic) = ((0.0577/(1+107.688-pH)) + (2.487/(1+10pH-7.688)) x MIN (2.85, 1.45*100.028*(25-T))

Fish Early Life Stages are Absent:

mg/L as N (Chronic) = ((0.0577/(1+107.688-pH)) + (2.487/(1+10pH-7.688)) * 1.45*100.028* (25-MAX(T,7))

[3] The 1-hour average concentration of total ammonia nitrogen (in mg/L as N) does not exceed, more than once every 3 years on the average, the acute criterion calculated using the following equation:

Class 3A:

mg/L as N (Acute) = (0.275/ (1+107.204-pH)) + (39.0/1+10pH-7.204))

[4] pH dependent criteria (Class 3A)

2.3. Reservoir Management

The manner in which water levels for the reservoirs under consideration are managed is of particular concern when addressing water quality issues. The timing of drawdown and the quantity of water present in a reservoir largely dictate water column processes and chemistry. Control and management of Rockport Reservoir and Echo Reservoir are under the jurisdiction of the Weber Basin Water Conservancy Districts and BOR, respectively.

Water management in Rockport and Echo Reservoirs is governed largely by water rights and has a significant effect on the timing and quantity of flow in the Weber River. Rockport Reservoir is designed to hold two seasons' worth of irrigation water and maintains a more stable water level than Echo Reservoir. In the spring, Rockport Reservoir is filled before Echo Reservoir, reducing the natural springtime flow in the Weber River between Rockport and Echo Reservoirs. Echo Reservoir is a drain and fill reservoir designed to store the equivalent of 1 years' worth of water rights. In a given year, most of the water rights from Echo Reservoir have been fulfilled by September, resulting in a significantly lower reservoir volume in October. Approximately 25,000 ac-ft of Echo Reservoir water right allotments are stored in Rockport Reservoir (personal communication, Ivan Ray, Davis and Weber Counties Canal Company and Erica Gaddis, SWCA Environmental Consultants [SWCA], March 26, 2012). Daily pool elevation, storage, inflow, and discharge data are available from the BOR for both reservoirs from the late 1960s to the present (Figure 2.1) (BOR 2012).

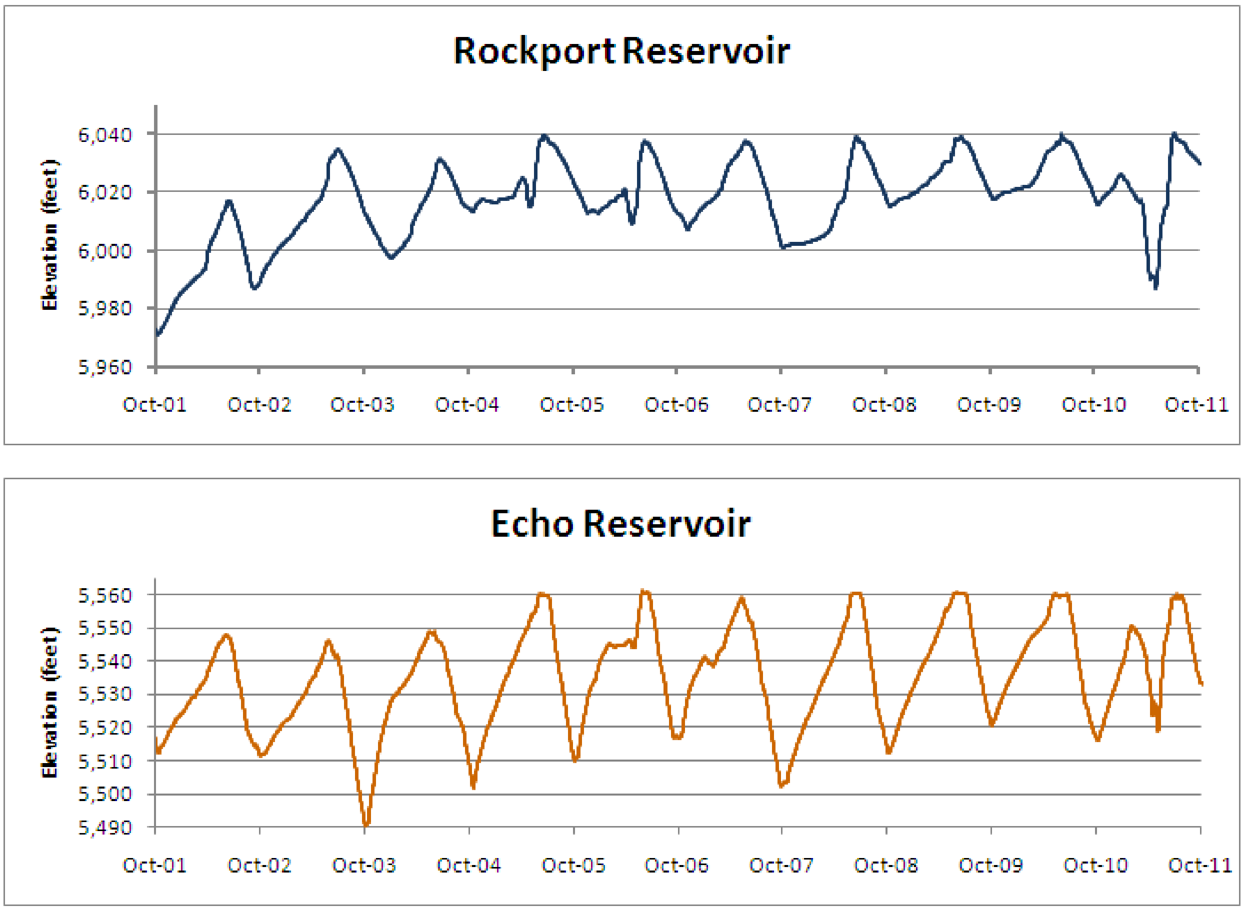

Figure 2.1. Reservoir pool elevation for Rockport and Echo Reservoirs from October 2001 through September 2011.

2.4. Beneficial Use Support Assessment for Rockport Reservoir and Echo Reservoir

This section summarizes reservoir profile data collected at the deepest sites near the dam of both reservoirs between 2002 and 2011 in order to validate the 303(d) listings for cold-water fishery DO standards. It also describes the current state of the fishery and the methods used to determine fishery health. The impairment confirmation analyses were based on Utah's most recent *Water Quality Assessment Guidance* (DWQ 2010).

2.4.1. Echo Reservoir

In all, 48 profiles collected near Echo Dam during the typical stratification season (May–October) were included in this analysis. In addition, two profiles were available from February to evaluate winter stratification. On average, 28% of the water column is below the minimum DO criterion when all life stages of cold-water fish species are present (Table 2.3). This exceedance typically occurs in August at the end of the reservoir stratification period. The early life stage DO criteria are not applicable to Echo Reservoir because there are no cold-water reproducing fish species in the reservoir (personal communication, Craig Schaugaard, Utah Division of Wildlife Resources [DWR], and Erica Gaddis, SWCA, April 10, 2012).

Table 2.3. Average Percentage of Water Column below Dissolved Oxygen Criteria for the Cold Water Fishery Use (3A) for Data Collected near Echo Dam (2002–2011)

Month	Average Percentage of Water Column Violating Minimum All Life Stage DO Criteria (>4.0 mg/L)
February	6%
May	0%
June	11%
July	37%
August	47%
September	9%
October	0%
Overall average	**28%**

The *Water Quality Assessment Guidance* (DWQ 2010) provides for evaluation of the water column overlap in temperature and DO exceedances. Often, by August, there is no habitat with temperatures below 20°C and DO greater than 4.0 mg/L (the minimum water quality criterion) (Table 2.4). Figures 2.2, 2.3, and 2.4 show profiles of oxygen and temperature across the season for selected years for data collected by DWQ at the Echo Dam monitoring station (4926130). Echo Reservoir does not violate the chronic DO standards of 5.0 mg/L over 7 days or the 30-day standard of 6.5 mg/L over 30 days. These standards are not applied to the deep areas of reservoirs (DWQ 2010). The average DO concentration in the surface of Echo Reservoir between 2002 and 2011 ranged from 7.1 to 8.6 and the minimum DO concentration observed was 6.6 mg/L (Table 2.5).

Table 2.4. Average Thickness of Habitat Layer that Meets the Cold Water Fishery Use (3A) for Temperature (<20°C) and Dissolved Oxygen (>4.0 mg/L) Criteria at the Echo Dam Site (2002–2011)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
February		–	–	–	–	–	–	–	22.0	26.0	24.0
May	–	–	–	–	–	27.4	–	–	–	–	27.4
June	25.6	12.0	11.0	24.9	29.8	22.4	–	–	29.1	26.0	22.5
July	0.0	12.5	–	0.0	–	4.1	–	–	23.0	28.9	6.8
August	6.6	–	0.0	16.4	0.0	0.0	0.0	–	0.0	0.0	3.4
September	–	4.0	–	13.0	–	6.9	–	–	17.5	22.0	10.5
October	15.0	6.5	–	–	–	–	–	–	–	–	10.8

Table 2.5. Average and Minimum Dissolved Oxygen Concentrations in the Epilimnion of Echo Reservoir

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Dam Site											
Average	7.6	8.7	8.5	7.7	7.9	8.5	–	–	9.5	9.8	8.6
Minimum	7.6	7.2	7.4	6.6	7.8	7.6	–	–	7.2	7.4	6.6
Count	1.0	3.0	2.0	3.0	2.0	3.0	–	–	3.0	3.0	20.0
Mid-lake											
Average	–	10.1	8.4	7.9	7.5	8.8	7.2	–	8.9	10.8	9.1
Minimum	–	8.7	7.7	7.1	7.5	8.3	7.2	–	7.8	8.0	7.1
Count	–	2.0	2.0	3.0	1.0	2.0	1.0	–	5.0	5.0	21.0

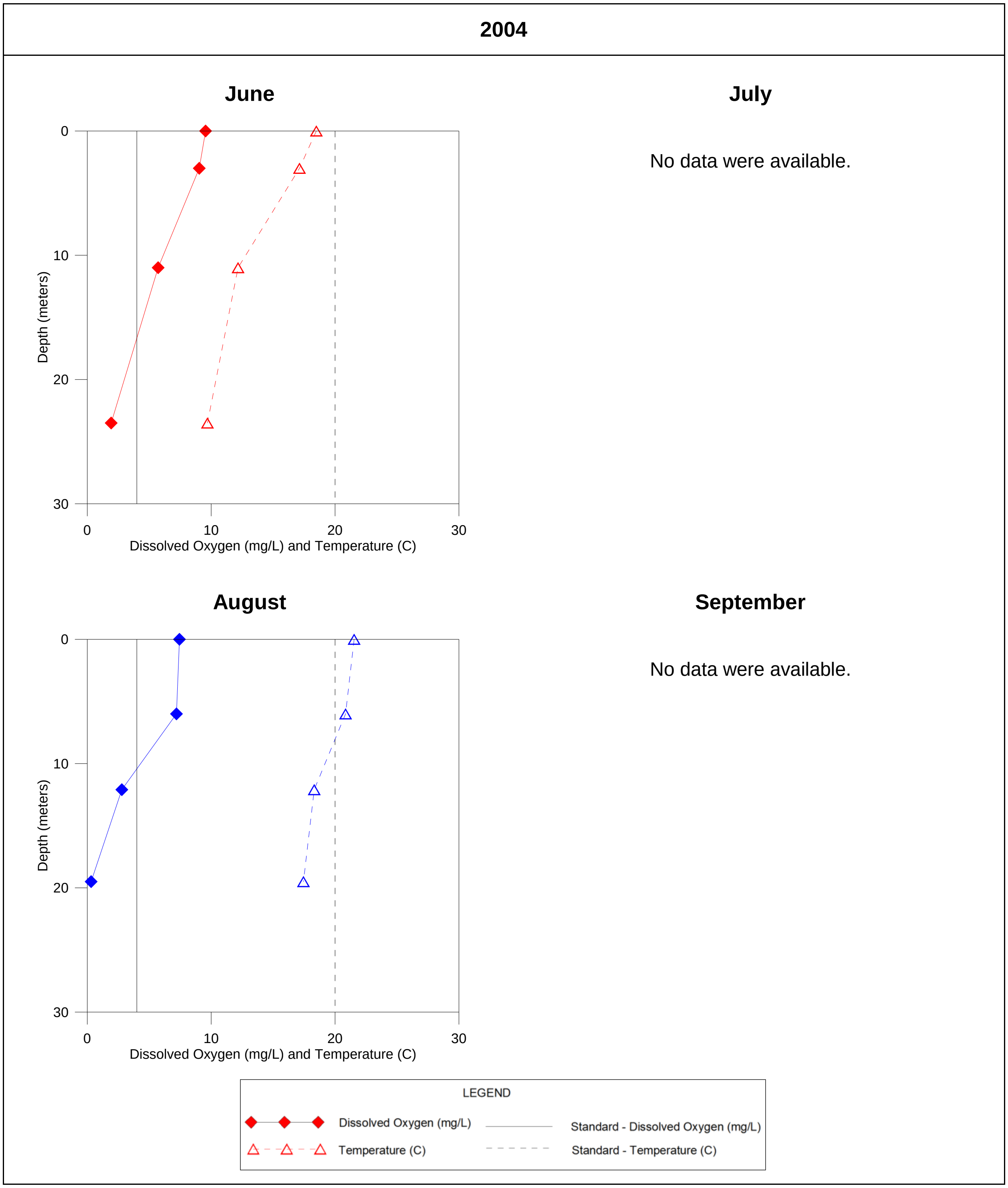

Figure 2.2. Dissolved oxygen and temperature graphs for the Echo Dam (DWQ station 4926130) in 2004.

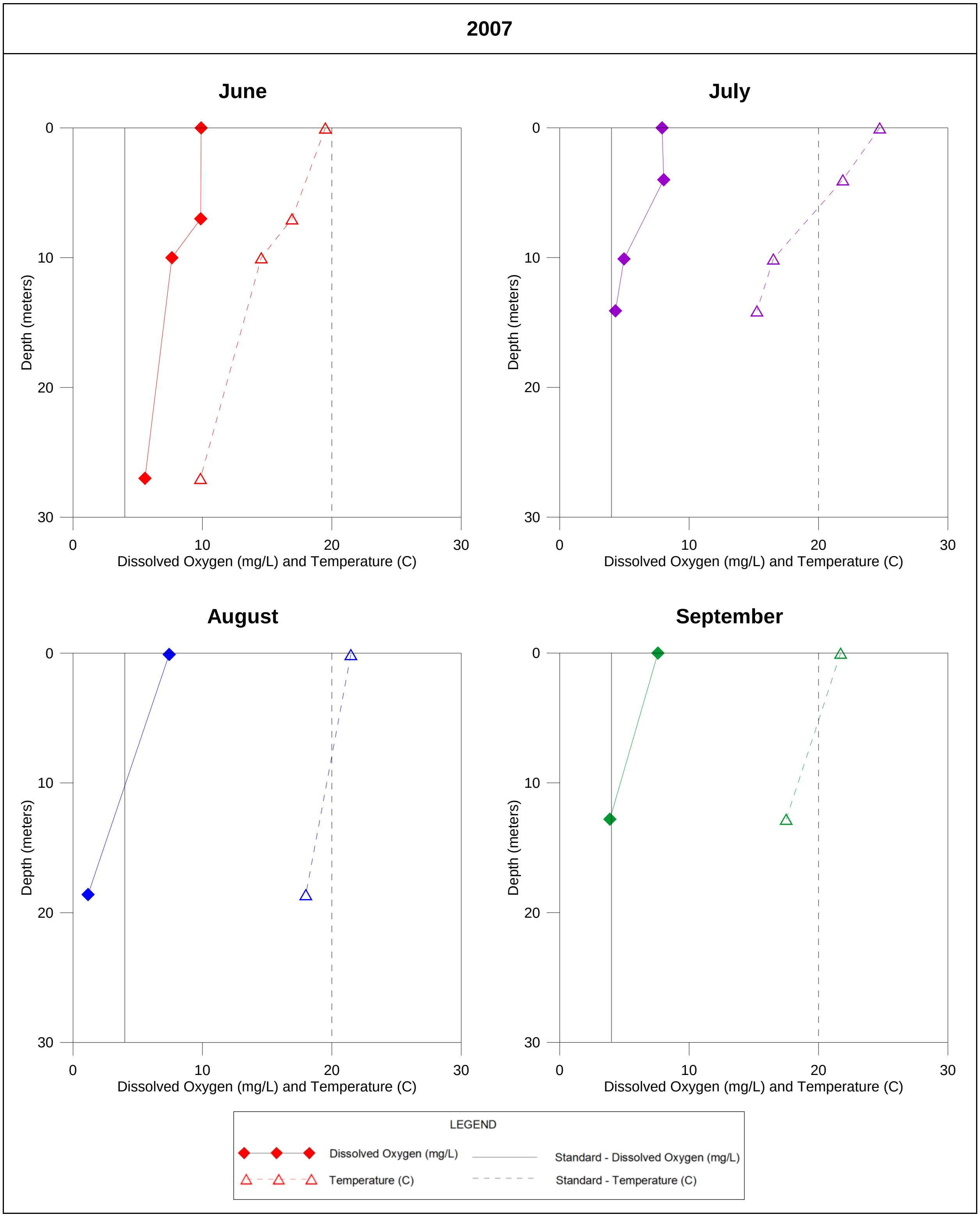

Figure 2.3. Dissolved oxygen and temperature graphs for the Echo Dam (DWQ station 4926130) in 2007.

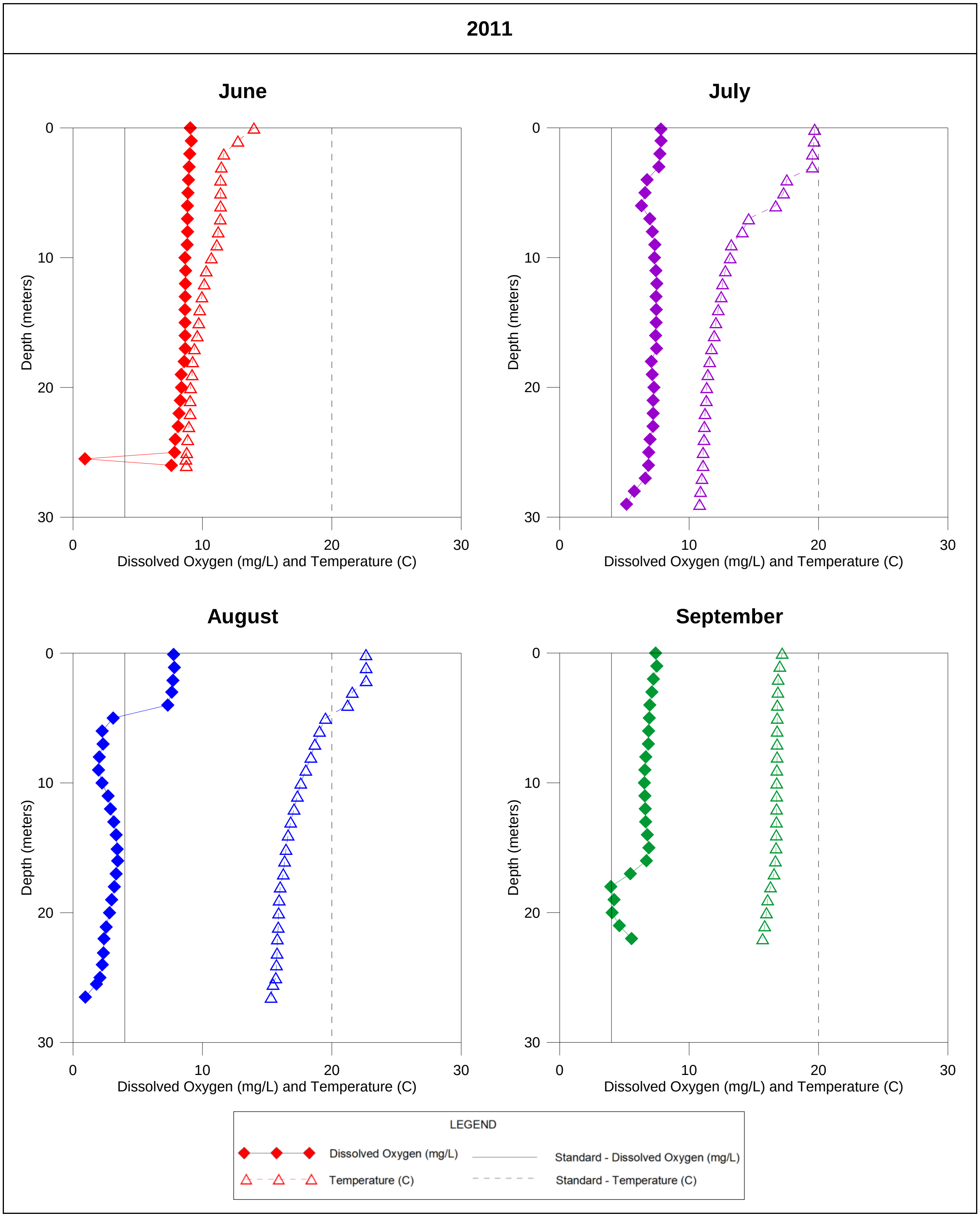

Figure 2.4 Dissolved oxygen and temperature graphs for the Echo Dam (DWQ station 4926130) in 2011.

2.4.2. Rockport Reservoir

In all, 32 profiles collected near Rockport Dam during the typical stratification season (May–October) were included in this analysis. In addition, one profile was available from February to evaluate winter stratification. On average, 29% of the water column is below the minimum water DO criteria when all life stages of cold-water fish species are present (Table 2.6). This exceedance typically occurs in August at the end of the reservoir stratification period. The early life stage DO criteria are not applicable to Echo Reservoir because there are no cold-water reproducing fish species in the reservoir (personal communication, Craig Schaugaard, DWR, and Erica Gaddis, SWCA, April 10, 2012).

Table 2.6. Average Percentage of Water Column below Dissolved Oxygen Criteria for the Cold Water Fishery Use (3A) at the Rockport Reservoir Dam Site (2002–2011)

Month	Minimum All Life Stage DO Criteria (>4.0 mg/L)
February	30%
June	14%
July	27%
August	51%
September	43%
Overall average	**29%**

On average, there is at least 2 m of habitat with temperatures below 20°C and DO greater than 4.0 mg/L (the minimum water quality criterion) throughout the stratification season (Table 2.7). The worst-case condition occurred in Rockport Reservoir in 2008, during which time no habitat met the minimum temperature and DO criteria from July through September. Figures 2.5, 2.6, and 2.7 show profiles of oxygen and temperature across the season for selected years for data collected by DWQ at the Rockport Reservoir Dam monitoring station (5923310). Rockport Reservoir does not violate the chronic DO standards of 5.0 mg/L over 7 days or the 30-day standard of 6.5 mg/L over 30 days. These standards are not applied to the deep areas of reservoirs (DWQ 2010). The average DO concentration in the surface of Rockport Reservoir between 2002 and 2011 was 8.0. Only once during this 10-year period was a measurement observed below the standards (July and August 2008). Other than this anomalous year, DO in the epilimnion never goes below the 30-day standard of 6.5 mg/L (Table 2.8).

Table 2.7. Average Thickness of Habitat Layer that Meets the Cold Water Fishery Use (3A) Temperature (<20°C) and Dissolved Oxygen (>4.0 mg/L) Criteria at the Rockport Reservoir Dam Site (2002–2011)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
February	–	–	–	–	–	–	–	–	19.0	22.0	20.5
June	10.8	–	11.0	–	33.2	30.6	24.0	37.3	37.7	32.5	27.5
July	–	–	–	–	–	13.3	0.0	4.0	36.1	–	13.4
August	16.8	–	0.0	–	0.0	–	0.0	9.1	20.0	21.0	9.6
September	–	–	–	–	–	–	32.7	0.0	21.0	16.0	17.4

Table 2.8. Average and Minimum Dissolved Oxygen Concentrations in the Epilimnion of Rockport Reservoir

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Dam Site											
Average	–	–	9.1	–	7.1	–	5.4	8.3	9.5	8.9	7.9
Minimum	–	–	9.1	–	7.1	–	2.7	7.5	7.5	7.1	2.7
Count	–	–	1.0	–	1.0	–	4.0	3.0	3.0	4.0	16.0
Mid-lake											
Average	9.7	–	8.6	–	–	–	4.4	8.4	9.3	9.3	8.0
Minimum	9.7	–	8.6	–	–	–	2.9	7.5	7.6	7.5	2.9
Count	1.0	–	1.0	–	–	–	3.0	2.0	3.0	3.0	13.0

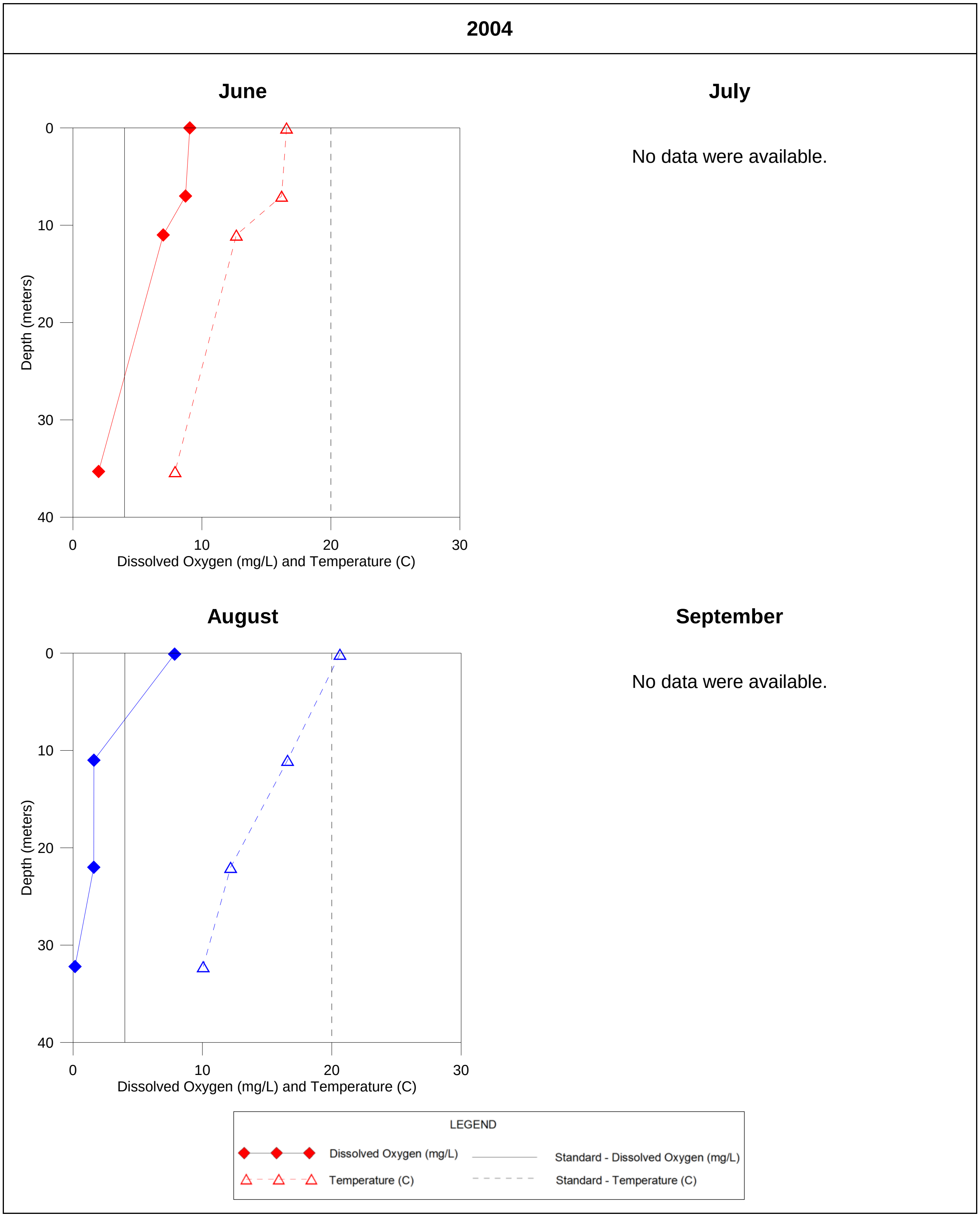

Figure 2.5. Dissolved oxygen and temperature graphs for the Rockport Reservoir Dam (DWQ station 5923310) in 2004.

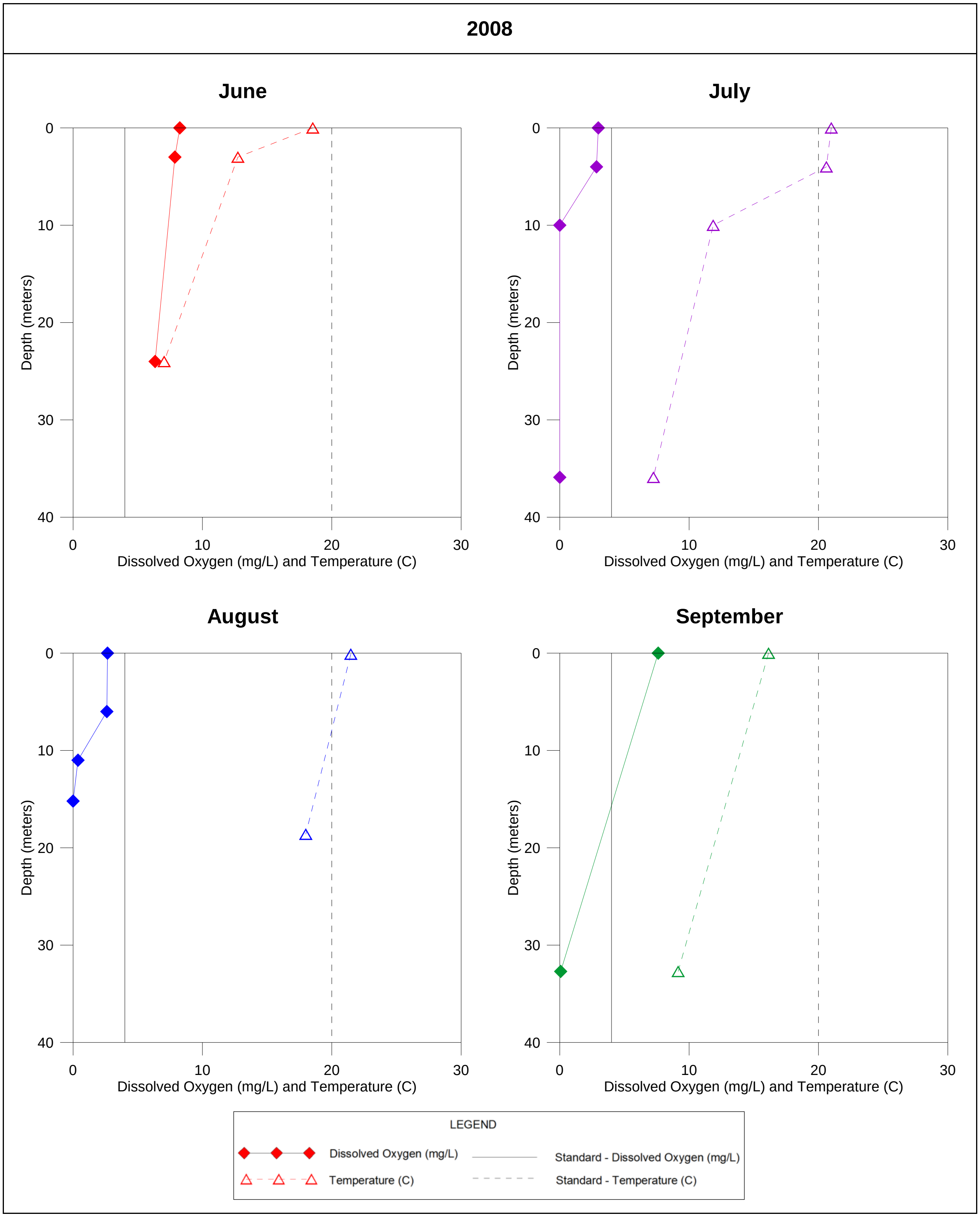

Figure 2.6. Dissolved oxygen and temperature graphs for the Rockport Reservoir Dam (DWQ station 5923310) in 2008.

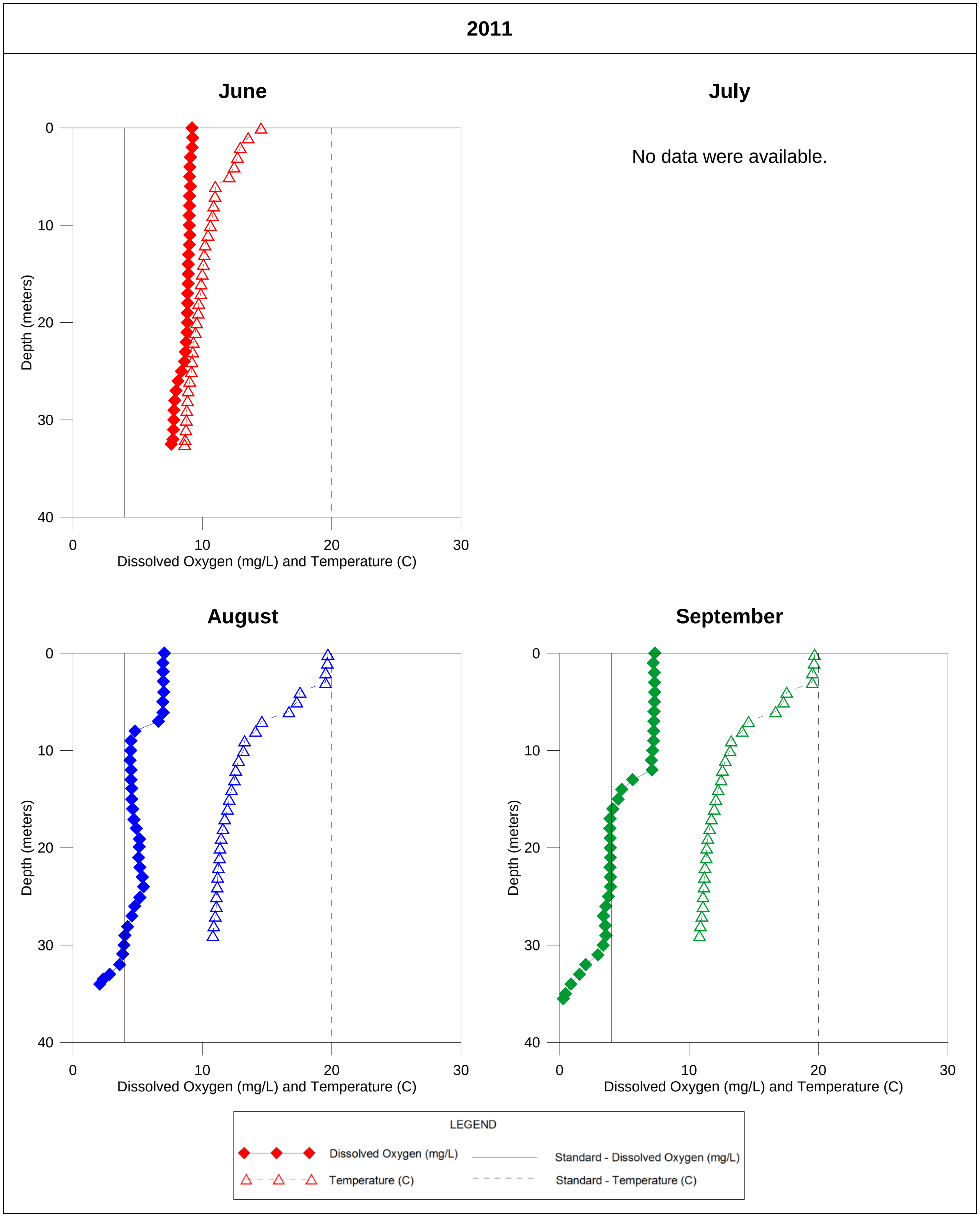

Figure 2.7. Dissolved oxygen and temperature graphs for the Rockport Reservoir Dam (DWQ station 5923310) in 2011.

2.4.3. Reservoir Fishery Health

Every 2–3 years, fish surveys of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*)are conducted in both Rockport and Echo Reservoirs by DWR to evaluate trends in the fish community. Results of these surveys are used to determine the health of the fishery and provide information that can improve the effectiveness of management actions (such as intensive stocking of trout) or can assist in detecting changes and preventing problems before the fishery impacts angling opportunities (DWR 2012). Health is assessed through a fish condition index that uses relative weight as a primary determinant (personal communication, Chris Penne (DWR), and Erica Gaddis (SWCA), January 10, 2014). Relative weight is generated by comparing the actual weight of a fish to a standard weight for fish of the same length. Fisheries literature indicates that a healthy relative weight target is an index value of between 95 and 105 (Anderson 1980) and most present-day biologists agree that although 100 is the optimal target, the target range is between 95 and 105 (personal communication, Chris Penne (DWR), and Erica Gaddis (SWCA), January 10, 2014). Recent fish surveys in both Rockport and Echo Reservoirs have reported relative weights within the target range and were deemed in good condition and able to find adequate habitat and forage (DWR 2008, 2012; Table 2.9). Therefore, the fishery is currently in good health. The TMDL aims to protect the current fishery and improve health further by providing more favorable oxygen conditions.

Table 2.9. Fish Condition Data for Rockport and Echo Reservoirs (unitless index of mean relative weight)

Reservoir	Rainbow Trout	Brown Trout
Rockport Reservoir		
2005	98	96
2007	100	96
2012	98	95
Echo Reservoir		
2004	98	95
2006	98	94
2008	98	96
2013	96	95

2.5. History of TMDL Development and Watershed Planning in Echo Reservoir Basin

Local, state, and federal agencies have written scientific and resource management reports that provide data and information pertinent to the current TMDL process. Some reports, such as *Weber River Basin: Planning for the Future* (DWaR 2009) and *Weber River Restoration Action Strategy* (Weber River Watershed Coalition 2003) provide background data on the setting and general conditions of the watershed. Other reports, such as the tributary TMDLs, have been completed and approved by the EPA (Table 2.10). Additional studies provide groundwater and surface water data that can be used in the modeling of historic conditions on the Weber River and Rockport and Echo Reservoirs (Table 2.11). Furthermore, although the Rockport and Echo Reservoir TMDL processes were initiated in 2003 (DWQ

2009), a TMDL for Echo Reservoir was completed in 2006 but was held in abeyance by the EPA until additional information was provided (EPA 2009).

Table 2.10. Lists of EPA-Approved TMDLs in the Upper Weber River Watershed Completed since 1995

Waterbody Name	Pollutant Listed	TMDL Date
Chalk Creek	Sediment, TP	October 1997
Silver Creek	Cadmium, zinc	August 2004

Note: Not all waterbodies have currently had assessments.

Table 2.11. Summary of Reports and Studies Relevant to the Echo and Rockport Reservoir TMDL Analysis and Implementation Planning

Topic	Year	Title	Author	Summary of Key Findings Relevant to TMDL Analysis
Tributary TMDL	2006	TMDL Water Quality Study of Echo Creek Watershed, Utah	UDEQ/DWQ	TMDL for sediment load reduction impairing cold-water fishery of Echo Creek, tributary to Weber River, downstream of Echo Reservoir. Contains watershed-wide source identification of sediment.
Tributary TMDL	2004	TMDL Water Quality Study of Silver Creek	UDEQ/DWQ	Defines impairment of Silver Creek for zinc and cadmium. Outlines hydrology of Silver Creek, a tributary to Weber River.
Groundwater hydrology	2003	Hydrology and Simulation of Groundwater Flow in Kamas Valley	U.S. Geological Survey (USGS)	Assesses groundwater and surface water data. Identified background nutrient data as well as sources of additional load.
Groundwater hydrology	2002	Geology of the Kamas-Coalville Region and Its Relation to Groundwater Conditions	Utah Geological Survey	Provides groundwater hydrology background for basin, including hydrostratigraphy and conductivity data.
Fishery	2008	Standard Electrofishing Surveys at East Canyon and Rockport Reservoirs during 2008	Benjamin K. Nadolski Craig J. Schaugaard (DWR)	Provides fisheries background information for beneficial use criteria.
Water quality	2001	Selected Hydrologic and Water Quality Data for Kamas Valley and Vicinity	USGS	Assesses water quality in Upper Weber River and Beaver Creek. Identifies high levels of phosphorous in groundwater.
Water management and planning	2003	Weber River Watershed Restoration Action Strategy	Weber River Watershed Coalition	Provides watershed background, description, and setting. Identifies sources of nutrient and sediment pollution and the strategy Weber River Coalition proposes for restoration and maintaining water quality in the basin.
Water management and planning	2009	Weber River Basin; Planning for the Future	DWR	Provides watershed background, description, and setting. Explains water management in watershed and source data including animal fee operations, stormwater discharges, and other sources of nutrient loading.
Groundwater hydrology	1984	Groundwater Reconnaissance of the Central Weber River area	USGS/DWR	Describes groundwater quality near Coalville.
Groundwater hydrology	1986	Water Resources of the Park City Area with Emphasis on Groundwater	USGS/DWR	Reviews water resources in the Park City area. Shows groundwater in the Silver Creek drainage exceeding state standards for several heavy metals and pH.
Source identification	2005	Clean Water Act Section 319 Nonpoint Source Pollution Control Program Watershed Project Final Report	Natural Resources Conservation Service (NRCS)	Identifies nonpoint source pollution to Chalk Creek, a tributary to Weber River. Identifies accomplished implementation projects to date, and identifies areas that still have room for adoption.
Source identification	1994	Chalk Creek Watershed; Coordinated Resource Management Plan	Soil Conservation Service–U.S. Department of Agriculture	Serves as a TMDL for sediment, phosphorous, and stream habitat impairment for cold-water fishery beneficial use. Provides proposed plan for sediment load reductions.

Table 2.11. Summary of Reports and Studies Relevant to the Echo and Rockport Reservoir TMDL Analysis and Implementation Planning

Topic	Year	Title	Author	Summary of Key Findings Relevant to TMDL Analysis
Source identification	1997–2011	Summit County Three Mile Landfill Monitoring Report	Five Star Engineers	Summarizes groundwater monitoring data, including nitrate measurements, up-gradient and down-gradient of landfill. The close proximity to Rockport Reservoir suggests that landfill leachage could reach Rockport Reservoir.
Echo Reservoir TMDL	2006	Echo Reservoir TMDL Water Quality Study	Cirrus Ecological Solutions, DWQ	Is the draft TMDL for Echo Reservoir. Contains source identification and watershed background data.
Echo Reservoir TMDL	2009	EPA Region VIII TMDL Review of Echo TMDL	EPA	Identifies additional information needed in draft TMDL.
Fishery	1998/2006	Revised Fish Hatchery Production Plan Final Environmental Assessment	U.S. Fish and Wildlife Service	Provides regulations for fish hatcheries in Utah, including the DWR Kamas Fish Hatchery in Kamas. Assists in identifying load from point source pollution in the watershed.
Fishery	2008	Fish Population Surveys at Lost Creek, Echo, Smith and Morehouse, Woodruff, and Birch Creek Reservoirs during 2008	Benjamin K. Nadolski Craig J. Schaugaard (DWR)	Provides fisheries background information for beneficial use criteria.
Fishery	1994	Emigration of Juvenile Rainbow Trout from a Mid-Elevation Utah Reservoir	Brad Schmitz, Utah State University, Master's Thesis	Identifies potential behavior of trout in Echo and Rockport Reservoirs. This document will assist in evaluating the spawning potential of rainbow trout, which will help identify degree of impairment as a cold-water fishery.

3. WATERSHED CHARACTERIZATION

3.1. Geology and Soils

3.1.1. Geology

Most surficial geologic features in the study watershed were formed in the Cretaceous and Eocene eras (from 145 to 34 million years ago) and include the Wasatch, Cotton, Flagstaff, Claron, and White Sage Formations. The Quaternary (most recent) formations consist of alluvial deposits along streams, lacustrine deposits in the valley, and glacial deposits at higher elevations. A summary of geologic formations in the study watershed is shown in Figure 3.1. Permian phosphatic (containing phosphorus) shales, found in the Park City Formation, also occur in the watershed (Figure 3.2). Erosion of these shales contributes phosphorus loading to surrounding surface waters.

3.1.2. Soils

Impacts to water quality from soils are due to stream bank erosion and excess nutrients associated with runoff and sediments washed into the stream. The soil groups that affect water quality at Rockport and Echo Reservoirs are generally the nutrient-rich loamy farmland soils near tributary streams. Soils in the watershed are not naturally high in phosphorus, with the exception of soils derived from the Park City Formation (Figure 3.3). As noted above, recent development in the subbasins where the phosphoric formation occurs has likely caused the erosion of phosphatic soils and increased phosphorus loading in East Canyon Creek (Olsen and Stamp 2000a).

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has collected soils data for the Rockport Reservoir and Echo Reservoir watersheds. The dominant soil types in the watersheds are shown in Figure 3.3, and soil texture and erodibility (K factor) are shown in Figures 3.4 and 3.5, respectively. Soil texture and erodibility are important characteristics for determining agricultural viability and soil stability. The erodibility of soils increases with its representative K factor, which is a function of soil organic matter, soil structure, particle size, soil permeability to water, and clay content. For example, soils high in clay content have a low K factor (0.05–0.15), whereas soils high in silt content generally have a high K factor (greater than 0.4) and are the most erodible type of soil. Soil textures and K factors by acre are presented in Tables 3.1 and 3.2, respectively. Most soils found in the watershed are loamy (i.e., a combination of sand, silt, and clay) and relatively erodible—the average K factor is greater than 0.25. This implies that sediment loads from tributaries to reservoirs should be relatively common.

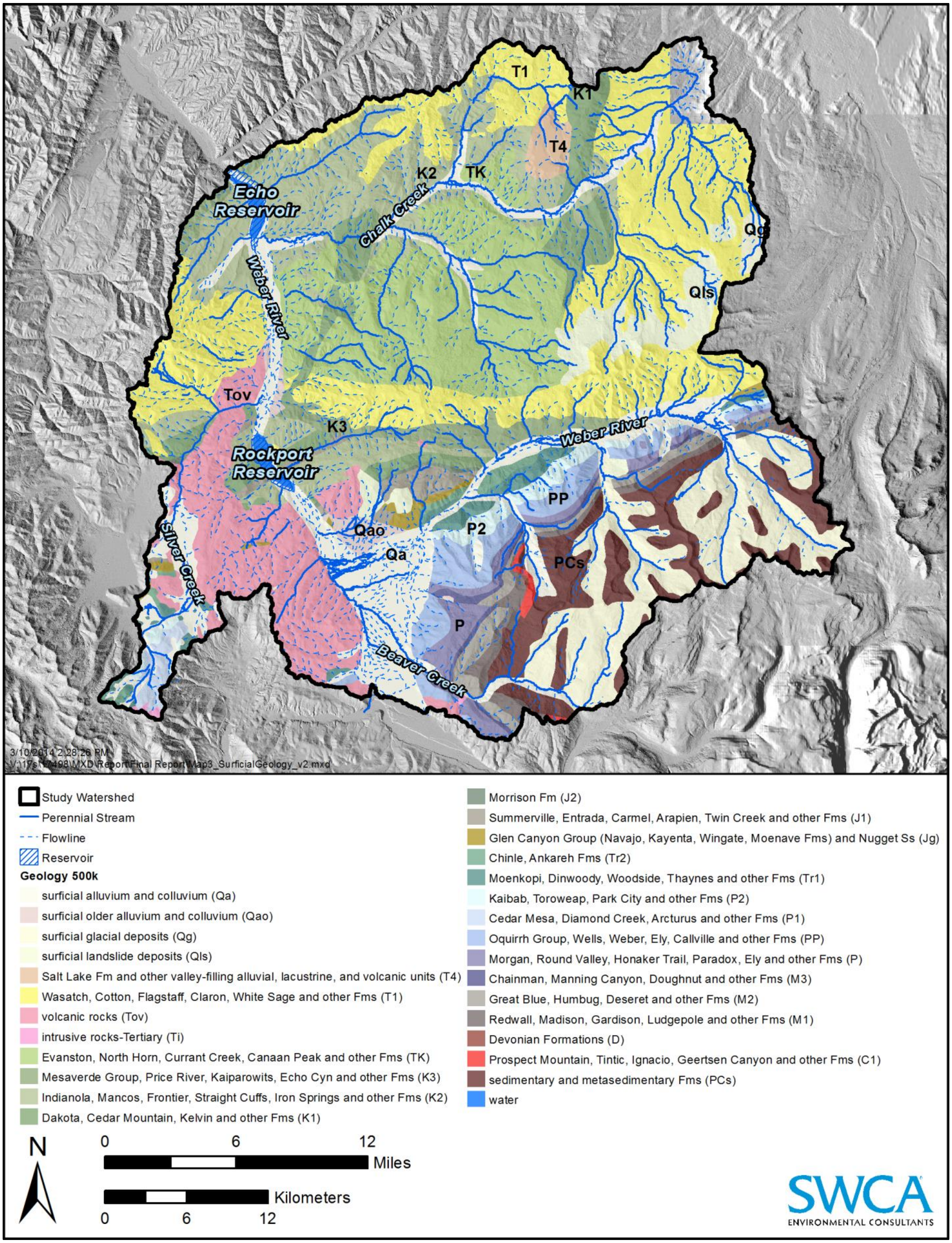

Figure 3.1 Map of geologic formations in the study watershed. (Utah Geologic Survey 2000).

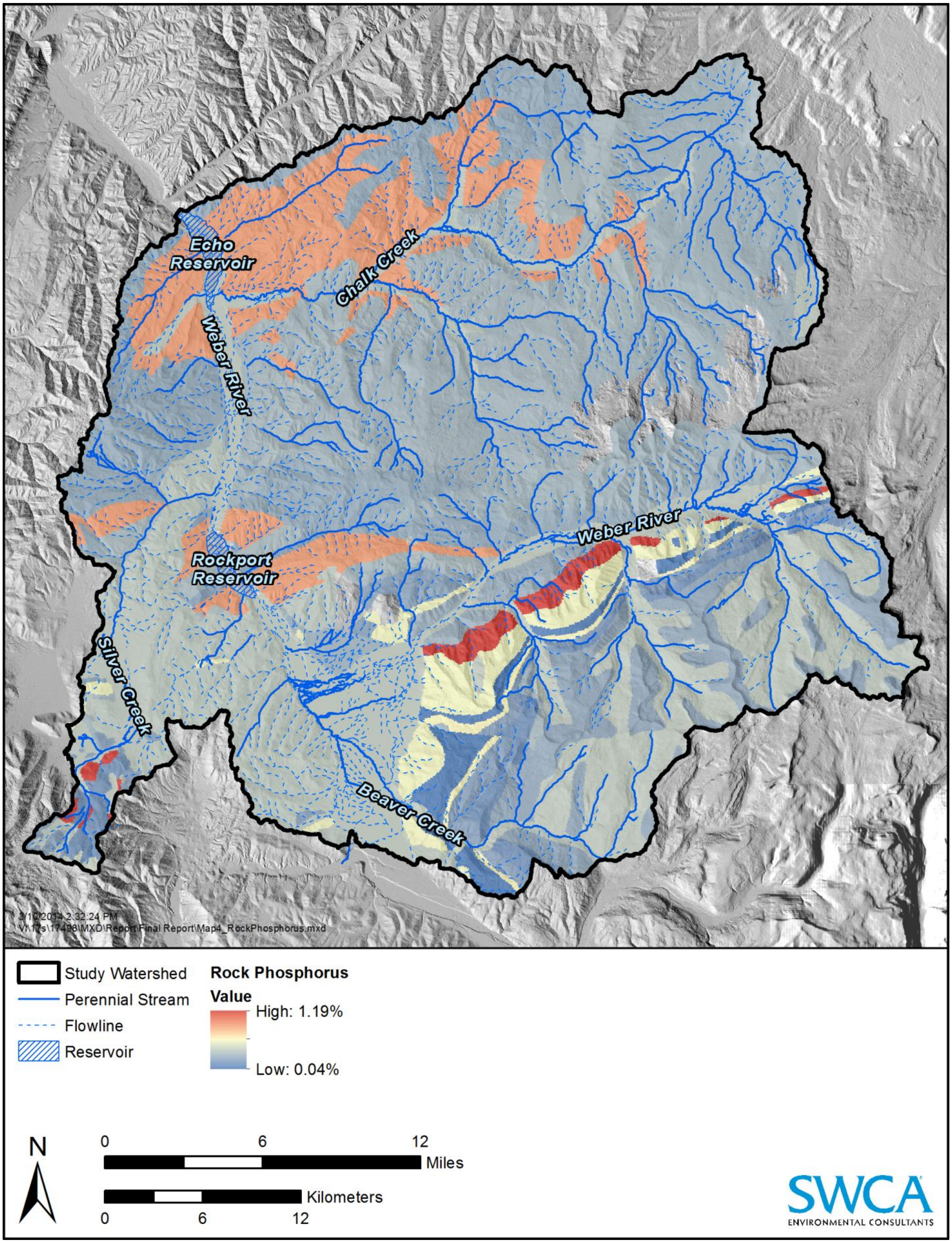

Figure 3.2. Map of rock phosphorus value in the study watershed.

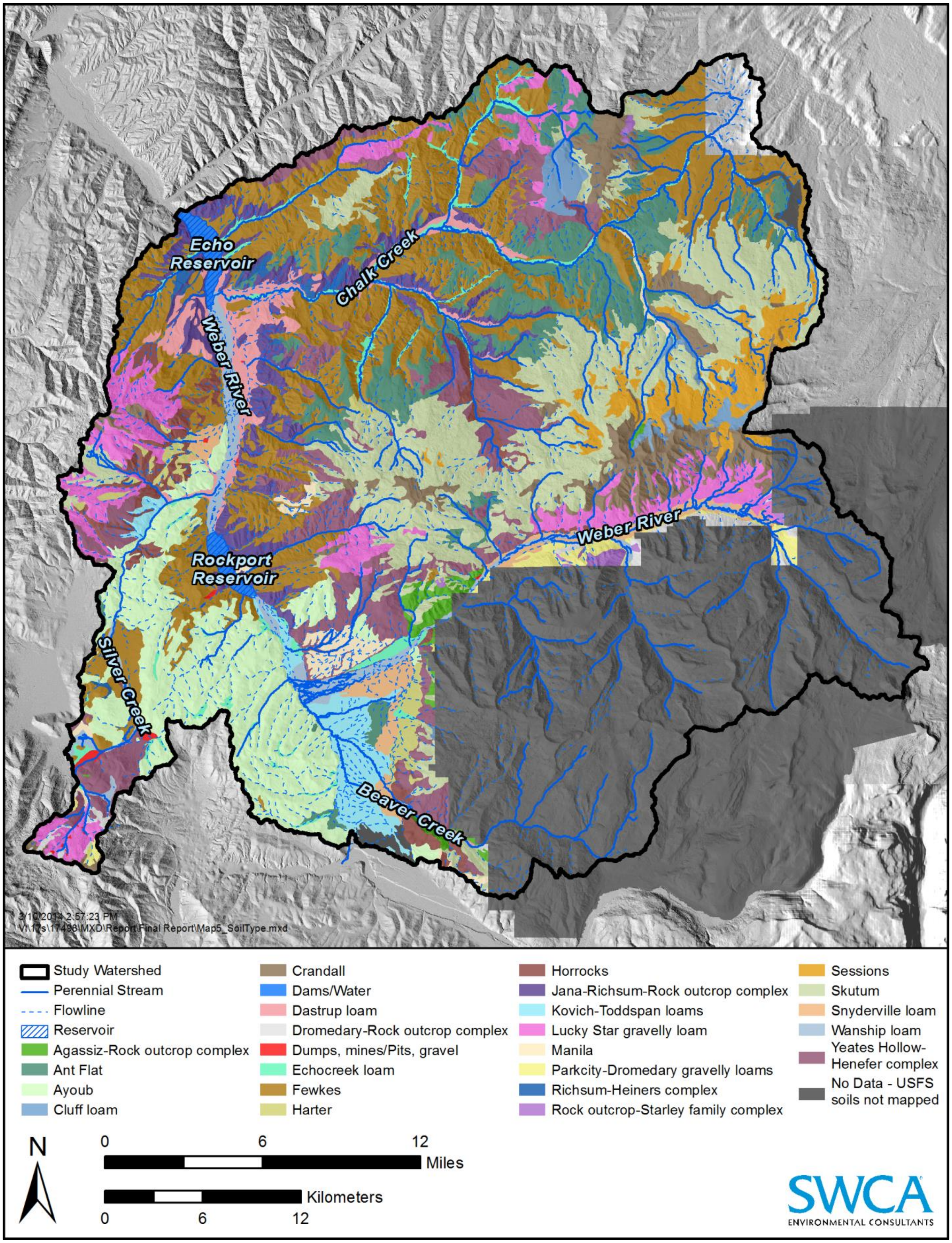

Figure 3.3. Soil types found throughout the study watershed.
Note: Data are available for USFS lands; however, they were not received prior to the analysis.

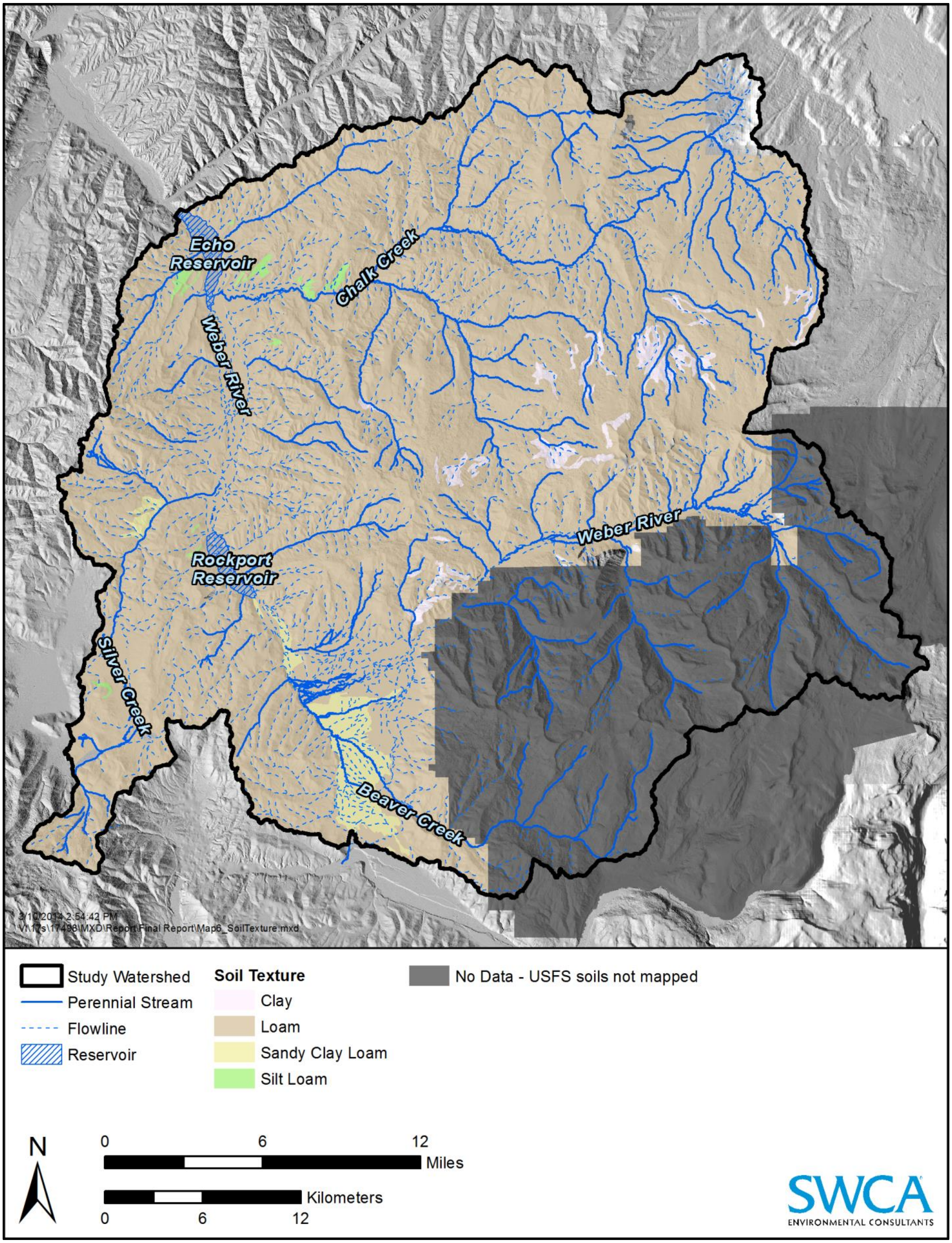

Figure 3.4. Map of soil textures in the study watershed.
Note: Data are available for USFS lands; however, they were not received prior to the analysis.

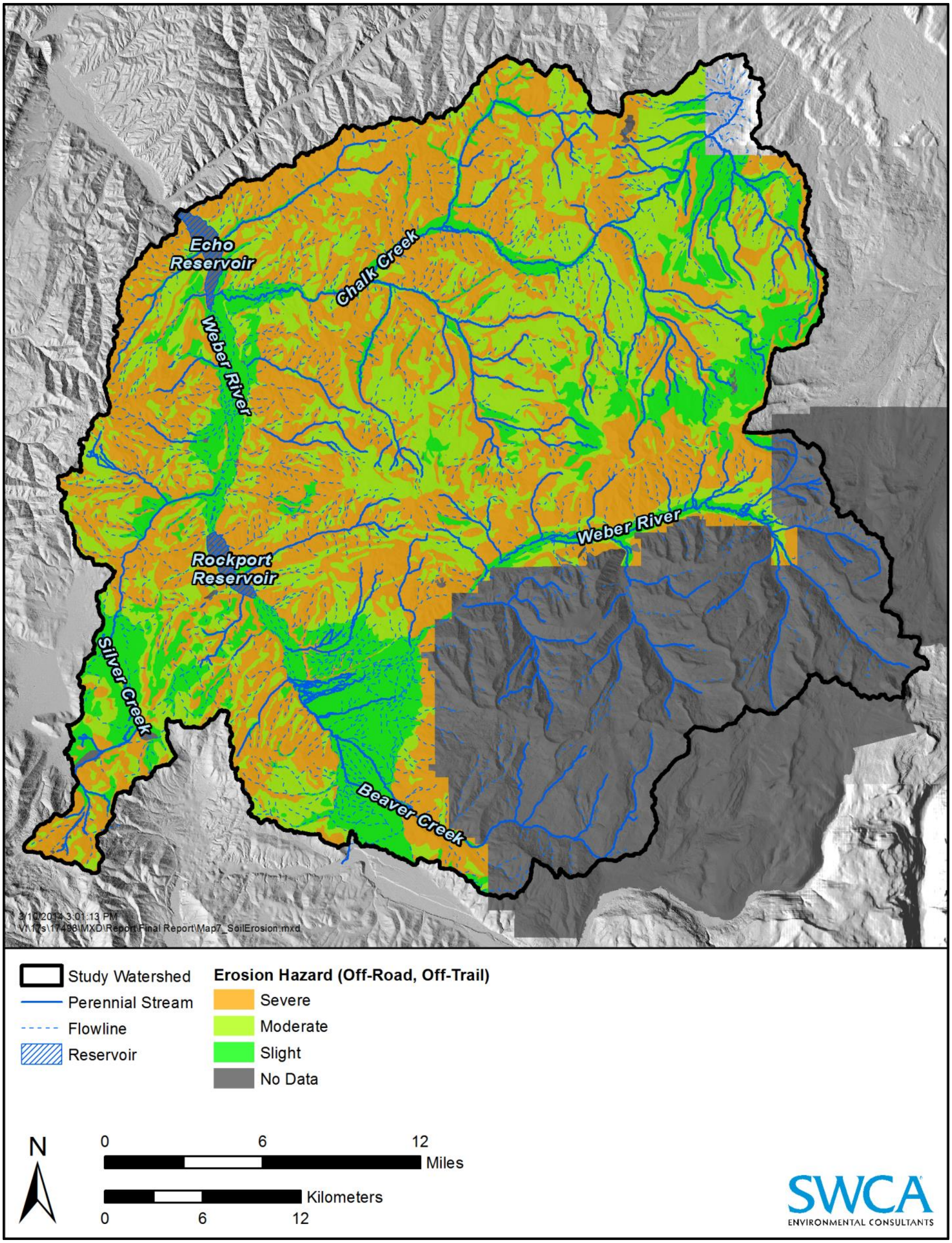

Figure 3.5. Map of erosive soil potential in the study watershed.
Note: Data are available for USFS lands; however, they were not received prior to the analysis.

Table 3.1. Soil Textures in the Study Watershed by Total Acres

Watershed	Cobbly Loam	Gravelly Loam	Loam	Sandy Loam	Silt Loam	Not Mapped
Echo Reservoir watershed	6,264	2,507	201,783	N/A	39,816	852
Rockport Reservoir watershed	24,437	N/A	157,749	20,179	9,265	1,031

Note: Data are available for USFS lands; however, they were not received prior to the analysis.

Table 3.2. Whole Soil K Factor by Acre for Rockport and Echo Reservoir Watersheds

Whole Soil K Factor	Echo Reservoir Watershed	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed	Percentage of Rockport Reservoir Watershed
0.02	N/A	N/A	7,407	3.48%
0.10	N/A	N/A	12,772	6.01%
0.15	2,507	1.00%	N/A	N/A
0.17	6,264	2.49%	24,437	11.49%
0.24	55,726	22.18%	28,260	13.29%
0.28	84,201	33.52%	17,621	8.29%
0.32	5,715	2.27%	53,686	25.24%
0.37	56,140	22.35%	58,182	27.36%
0.43	39,816	15.85%	9,265	4.36%
Not mapped	852	0.34%	1,031	0.48%

Note: Data are available for USFS lands; however, they were not received prior to the analysis.

3.2. Land Cover and Land Use

Land use is an important parameter to consider when determining nutrient and sediment loads to receiving waterbodies. For example, if the majority of a watershed were covered by agricultural operations, it would be expected that fertilizer-derived nutrients would make up an important component of the total nutrient load. Land cover data for the Rockport Reservoir and Echo Reservoir watersheds were obtained from the 2006 National Land Cover Data program (Fry et al. 2011). Results indicate that for the watersheds under consideration, land cover is dominated by forests and rangeland, while parks, agriculture, and highways represent the least amount of land cover (Table 3.3 and Figure 3.6). These results would imply that nutrient loads from agricultural sources should be minimal when compared to loads from other sources.

Table 3.3. Land Cover Categories for Rockport Reservoir and Echo Reservoir Watersheds

Category	Echo Reservoir Watershed (acres)	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed (acres)	Percentage of Rockport Reservoir Watershed
Agricultural	668	0.27%	218	0.10%
Alfalfa	1,659	0.66%	1,420	0.67%
Barren	459	0.18%	4,766	2.24%
Forest	133,487	53.14%	143,074	67.28%
Hay	2,288	0.91%	2,959	1.39%
Highway	257	0.10%	0	0%
Park	344	0.14%	95	0.04%
Pasture	5,417	2.16%	12,394	5.83%
Rangeland	91,219	36.31%	38,271	18.00%
Urban	8,671	3.45%	4,952	2.33%
Urban low density	2,523	1.00%	1,109	0.52%
Water and wetlands	4,231	1.68%	3,405	1.60%

3.3. Fisheries and Wildlife

The areas surrounding Rockport and Echo Reservoirs are home to various wildlife species, and both reservoirs are popular fishing and recreational destinations. Fish species in the reservoirs include rainbow trout, brown trout, and small mouth bass. The DWR has managed these reservoirs as a "put-grow-and-take" trout fishery since the 1960s and stocks them annually (Schmitz 1994). The reservoirs are managed as "two-story" fisheries in which warm-water species are supported in the upper layers of the reservoirs and cold-water species are supported in the lower layers (personal communication, Chris Penne, DWR, and Erica Gaddis, SWCA, July 3, 2013).

Big-game species in the watershed include mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis)*, and moose (*Alces alces*). Common mammals in the area include yellow-bellied marmot (*Marmota falviventris*), gophers (*Thomomys spp.*), coyotes (*Canis latrans*), porcupines (*Erethizon dorsatum*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*). Common waterfowl and shorebird species in and around the reservoirs include mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), northern pintail (*Anas acuta*), teal (*Anas spp.*), redhead (*Aythya americana*), Canada goose (*Branta Canadensis*), sandhill crane (*Grus Canadensis*), killdeer (*Charadrius vociferous*), great blue heron (*Ardea alba*), Clark's grebe (*Aechmorphorus clarkia*), western grebe (*Aechmorphorus occidentalis*), gulls (*Larus spp.*), and plovers (*Pluvialis spp*.). It is likely that some of these waterfowl and shorebird species use riparian habitats along tributary streams, as well.

3.4. Landownership

Landownership in the Echo Reservoir and Rockport Reservoir watersheds is split among private, federal lands, and state-owned lands (Figure 3.7). Private landownership makes up the largest portion (77.0%), whereas federal lands (U.S. Forest Service [USFS] and Bureau of Land Management [BLM]) and state lands (state parks, trust lands, and wildlife management areas) make up the remaining 22% and 1%, respectively (Table 3.4).

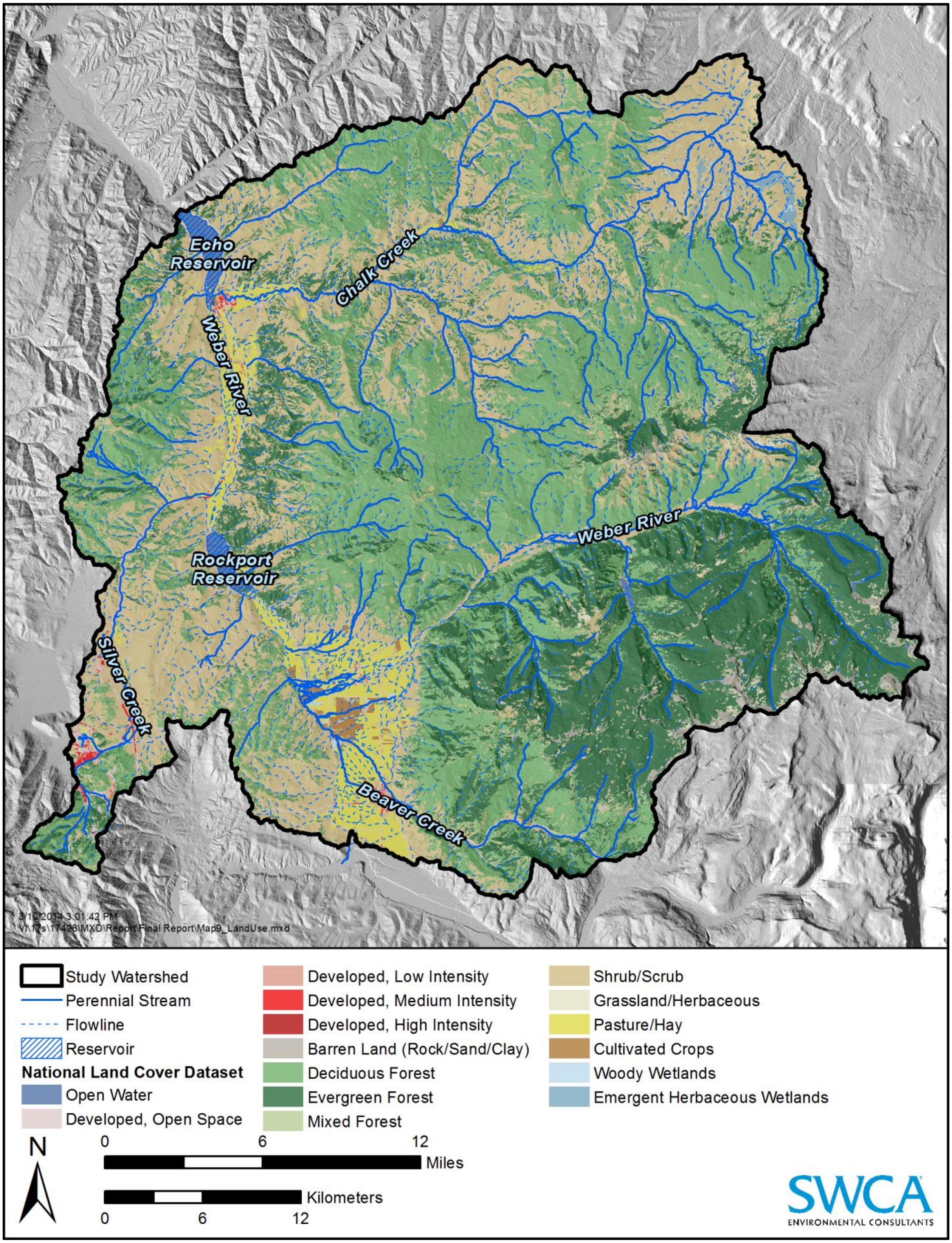

Figure 3.6. Map of land use and land cover in the study watershed.

As discussed previously, agriculture in Summit County makes up relatively small part of the economy, joining forestry, fisheries, hunting, and mining to total only1.6% of industry in Summit County (U.S. Census Bureau). However, the social connection to historic land use is important in the local communities. While the proportion of land used for agriculture has decreased, agriculture has contributed and continues to contribute to the area's sense of place and visual quality. Between 2002 and 2007, the area of land used for agriculture in Summit County increased 10% from 375,689 acres to 414,928 acres. Agricultural land uses in Summit County are dominated by grazing or pasture land (92%), followed by cropland (7%) and other uses (1%) (National Agricultural Statistics Service 2007).

Table 3.4. Landownership for Rockport Reservoir and Echo Reservoir Watersheds

Category	Echo Reservoir Watershed (acres)	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed (acres)	Percentage of Rockport Reservoir Watershed
BLM	294	<1%	156	<1%
USFS	0	0%	100,254	47%
Private	249,315	99%	108,969	51%
State parks and recreation	125	<1%	1,736	<1%
State trust lands	1	<1%	280	<1%
State wildlife reserve/management area	1,487	<1%	1,268	<1%
Total	251,222	100%	212,663	100%

3.5. Stream Hydrology

In order to determine a TMDL for the reservoirs under consideration, it is crucial to understand how and where loads are delivered. Therefore, a stream hydrology assessment is needed. The main pathway through which loads are delivered to the reservoirs is the Weber River. In the watershed addressed in this TMDL, the Weber River drains 725 square miles of the western slope of the Uinta Mountains and connects Rockport and Echo Reservoirs. Its major tributaries are Smith and Morehouse Creek, the South Fork of the Weber River, Beaver Creek, Silver Creek, and Chalk Creek. For clarity in this report, the Weber River is divided into two segments: the stream network above Rockport Reservoir and the stream network above Echo Reservoir (i.e., below Rockport Reservoir).

3.5.1. Stream Network above Rockport Reservoir

The first major tributary to enter the Weber River is Smith and Morehouse Creek at river mile 21.3 (measured upstream from the Wanship Dam at river mile 0.0). The Smith and Morehouse Reservoir is approximately 6.0 miles upstream from the confluence of Smith and Morehouse Creek and the Weber River. The Smith and Morehouse Reservoir has a storage capacity of approximately 8,345 ac-ft.

Below the Smith and Morehouse Creek confluence, the Weber River flows west, receiving flows from several smaller tributaries from the north. At river mile 16.5, the South Fork of the Weber River joins the Weber River. The Weber River then turns north and is joined by Beaver Creek, the largest tributary in this segment of the river, at river mile 7.9. The Weber River then flows into Rockport Reservoir, which at full capacity has a surface area of 1,189 acres and storage capacity of approximately 62,100 ac-ft. Figure 3.8 is a stem diagram of the Weber River from its headwaters to Rockport Reservoir, including major tributaries and diversions.

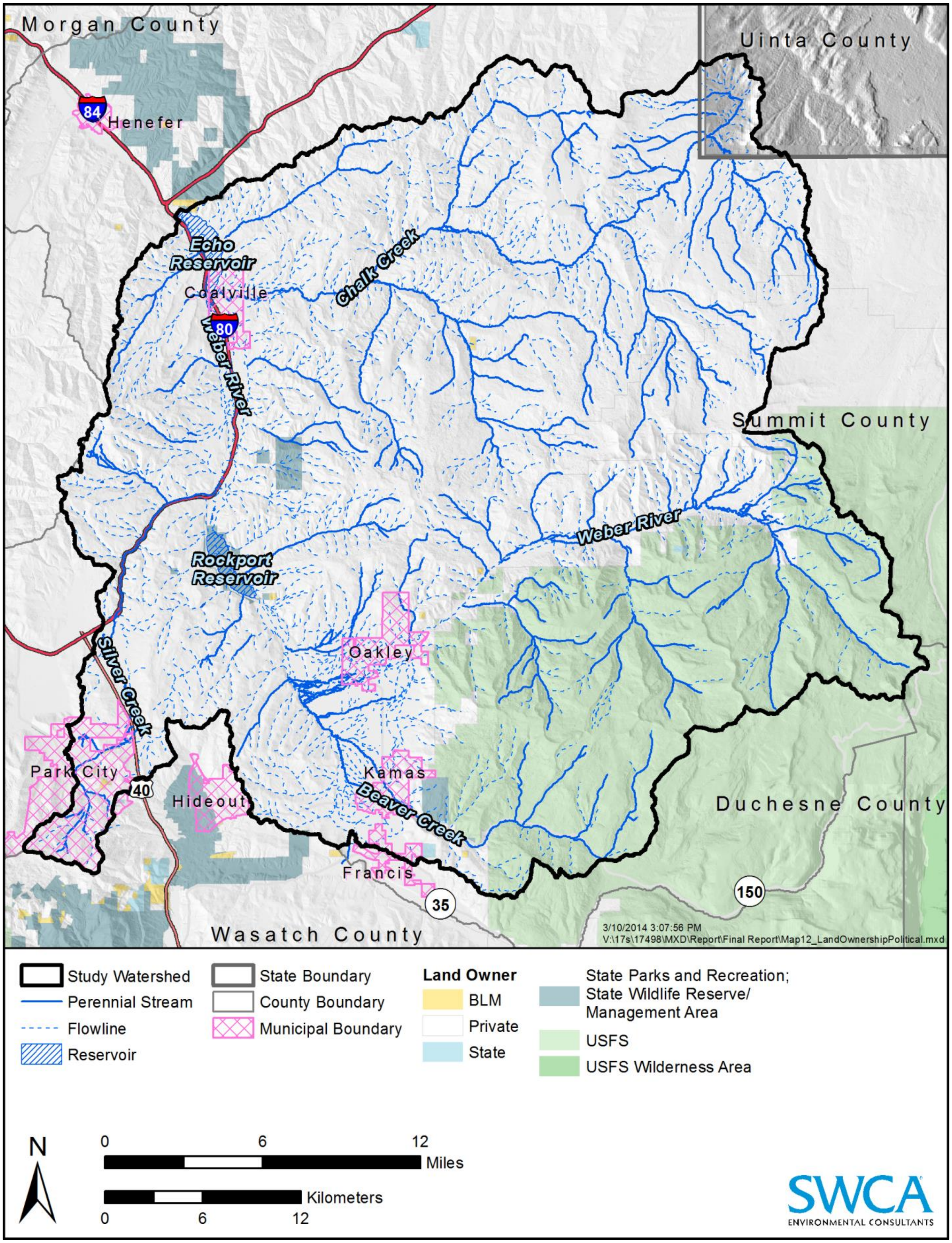

Figure 3.7. Map of landownership in the study watershed.

3.5.2. Stream Network above Echo Reservoir

Water released from the Wanship Dam at Rockport Reservoir flows north for approximately 2 miles before it is joined by Silver Creek at river mile 13.6 (measured upstream from Echo Dam). The Weber River then flows north through agricultural lands for another 8.0 miles before entering Echo Reservoir, which is a shallower reservoir having a surface area of 1,455 acres and a storage capacity of approximately 74,000 ac-ft. The largest tributary to this segment of the river is Chalk Creek, which flows directly into Echo Reservoir when the reservoir is at full capacity; otherwise, it flows into the Weber River at river mile 5.0. Figure 3.9 illustrates a stem diagram of the Weber River from Rockport Reservoir to Echo Reservoir, including major tributaries and diversions.

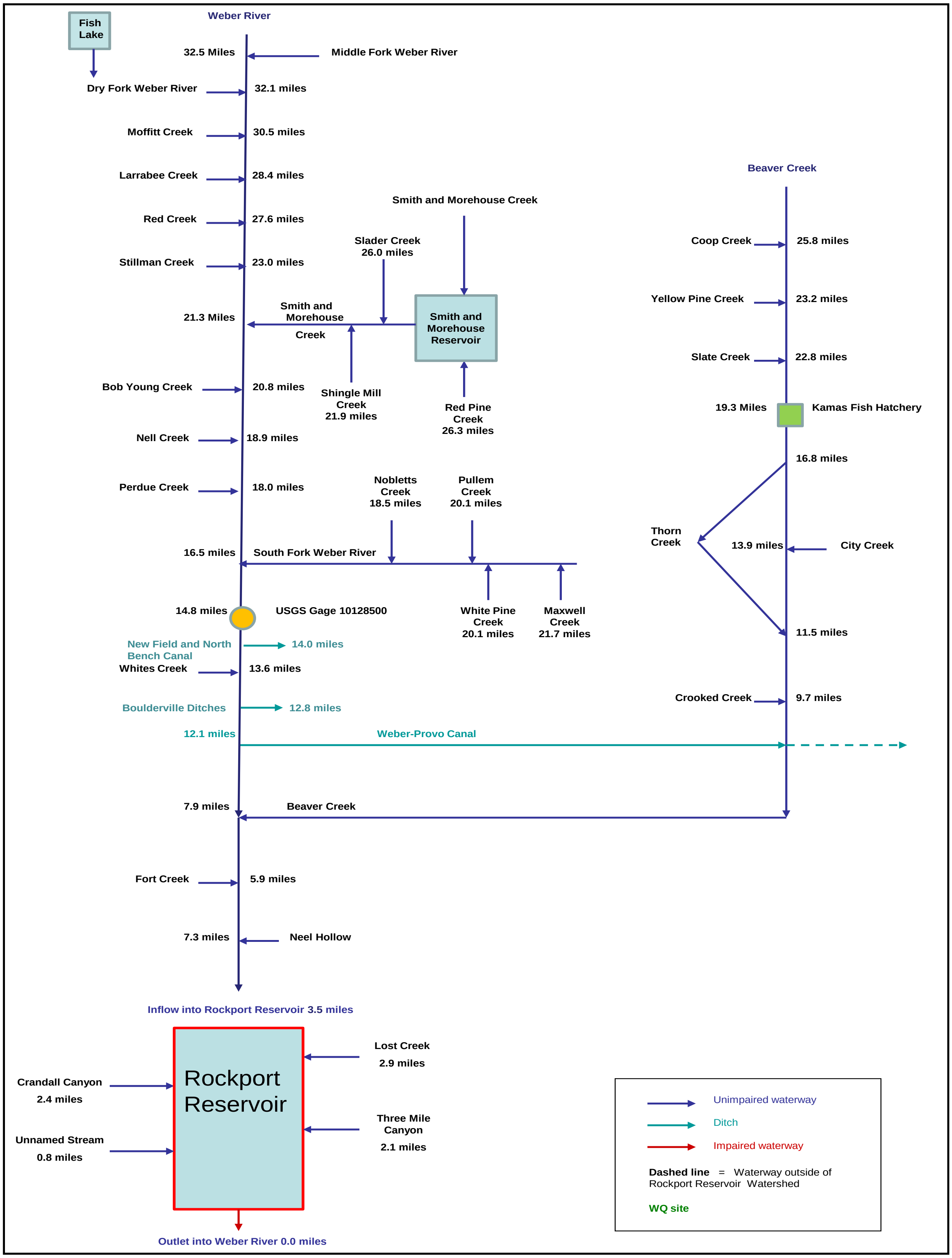

Figure 3.8. Stream network from Weber River headwaters to Rockport Reservoir (not to scale).

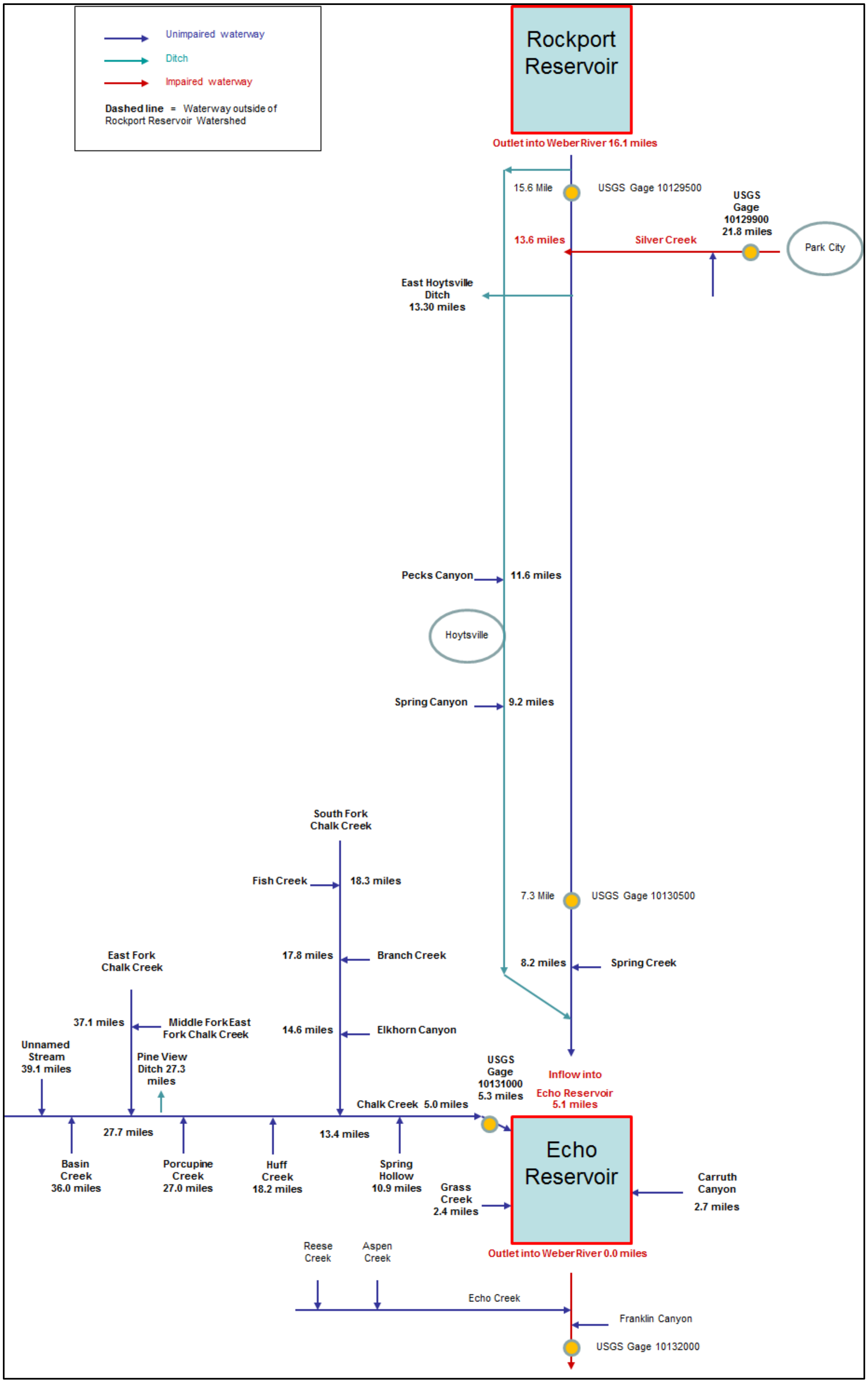

Figure 3.9. Stream network from Rockport Reservoir to Echo Reservoir (not to scale).

4. WATERSHED AND RESERVOIR MODELING

4.1. Model Goals and Objectives

Developing the TMDL for the Rockport and Echo Reservoirs involved using two models: BATHTUB and the Soil and Water Assessment Tool (SWAT). BATHTUB is an empirical reservoir model based on data from over 500 reservoirs across the United States. BATHTUB models nitrogen and phosphorus loads for reservoirs to determine algal growth and DO depletion rates during stratification. It is also used to model reservoir management scenarios and to determine load reductions required to achieve water quality targets. SWAT is a spatially distributed watershed model that simulates hydrology, plant growth, and nutrient and sediment transport processes in a watershed. Simply put, SWAT was used to model relative contribution of nutrient loads to the reservoirs associated with watershed sources, and BATHTUB was used to model load effects within reservoirs.

For modeling purposes, separate watershed and reservoir models were created for the Rockport Reservoir watershed and the Echo Reservoir watershed (Figure 4.1). The Rockport Reservoir watershed includes the headwaters of the mainstem of the Weber River and Beaver Creek, a major tributary to the Weber River. The watershed area between the dam at Echo Reservoir and the dam at Rockport Reservoir is considered the Echo Reservoir watershed for SWAT modeling. Silver Creek and Chalk Creek are major tributaries that drain the Echo Reservoir watershed and flow into the Weber River above the Echo Reservoir.

There are two reasons for creating the two SWAT models for the TMDL. First, the split allows the BATHTUB model results for Rockport Reservoir to be easily incorporated into the Echo Reservoir watershed SWAT model as a release from Rockport Reservoir into the downstream watershed. Second, measured outflow data exist for Rockport, which eliminates the need to model and calibrate Rockport Reservoir releases as part of the hydrology in SWAT, thereby removing the uncertainty associated with simulating reservoir releases.

Baseline BATHTUB reservoir models were developed for several different conditions: dry weather and low reservoir level conditions, average weather and average reservoir level conditions, and wet weather and high reservoir level conditions. Each of these conditions has occurred since 2000. BATHTUB scenarios with varying levels of nutrient input from the watershed (as modeled from SWAT) as well as changes in reservoir operation were run and compared to the baseline model to determine the nutrient load reduction needed to meet water quality standards for DO.

4.2. Modeled Conditions and Seasonality

BATHTUB was configured to model representative dry (2004), average or expected normal (2007), and wet (2011) hydrologic conditions (Figure 4.2). Note that although 2004 was a dry year for most of the Weber River Basin, the flows above Rockport Reservoir are higher than in 2007. This is because although the region experienced a drought in 2004, the Rockport Reservoir drainage experienced high flows in the form of snow melt. The SWAT models were set up to run from January 1, 1998, to December 31, 2011. The years 1998 through 2001 are considered warm-up years. Warm-up years are the first years in a model run that allow the model to initiate plant growth and other watershed processes. However, the output for these years is not used in the analysis to reduce the effects of initial model conditions on results. The year 2007 is considered an average year for stream flow and reservoir level, and is used for modeling average conditions in the study watershed.

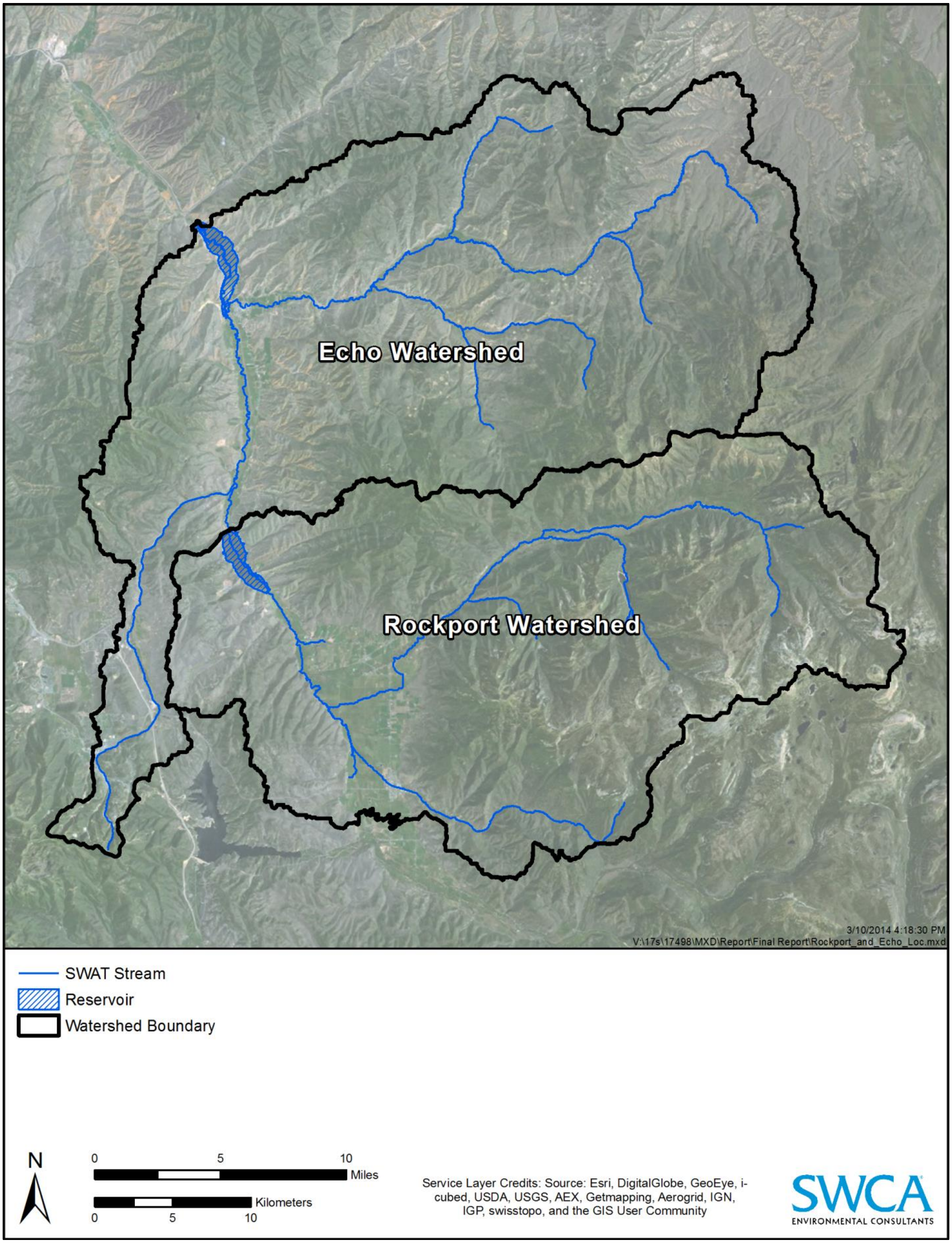

Figure 4.1. Subwatersheds in the study watershed.

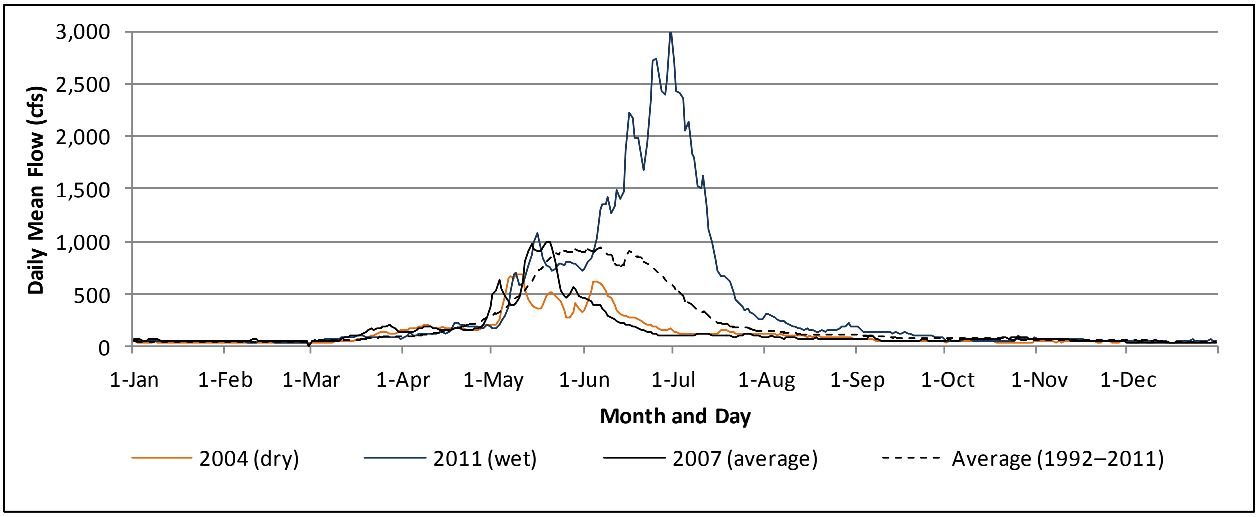

Figure 4.2. Dry, wet, and average year hydrographs for Weber River near Oakley, Utah (USGS gage number 10128500).

Seasonality was also an important consideration in determining modeling conditions with particular attention given to two important aspects: 1) the critical season for oxygen depletion in the hypolimnia of the reservoirs and 2) the distribution of nutrient loads across seasons. The critical season for oxygen depletion in the hypolimnia is the period in which the reservoirs are thermally stratified. It was determined that the reservoirs are typically thermally stratified from May 15 to September 30. These dates were selected based on an evaluation of all available temperature and DO profile data. DO and temperature profile data from the years 2004, 2007, and 2011 were used to further validate the use of this stratification season assumption for all of the conditions modeled.

Although the stratification period lasts for 137 days (May 15 through September 30), the critical season for nutrient loading to the reservoirs begins with the spring melt period, assumed to begin on April 1. Nutrient loads to the reservoir for the summer season used in the TMDL analysis extend from April 1 through September 30. The seasonal loads are important because spring runoff and summer storm events tend to generate most of the sediment and nutrients from the watersheds. The reservoirs are drawn down significantly each fall and fill again in the spring. Nutrient loads from the watershed are smaller during the winter, which is not a critical period for algal growth or oxygen depletion in the reservoirs. Internal load typically represents load from previous years or seasons (e.g., winter) that is re-suspended and that contributes to summer nutrient concentrations at the surface. However, the inlet and outlet data from both reservoirs indicate that the reservoirs are a net sink for nutrients during the critical summer season. Therefore, no internal loading of nutrients to the reservoir surface is assumed for the summer stratification season (see section 6.3).

4.3. Watershed Model: Soil and Water Assessment Tool

SWAT is used to predict the effect of management decisions on water, sediment, nutrient, and pesticide yields with reasonable accuracy on large, ungaged river basins (Gassman et al. 2007). SWAT is an interdisciplinary watershed modeling tool that has been used to conduct a variety of analyses, including hydrologic studies, pollutant load assessments, climate change impacts, and TMDLs (Gassman et al. 2007). The USDA’s Agricultural Research Service created the SWAT model and continues to update the model and provide technical support for users. For the TMDL analysis, SWAT 2012 Version 591 was run using ArcGIS 10.0 SP5.

SWAT models watershed processes at a subbasin scale (see Figure A-1 in Appendix A). Each watershed was split into subbasins based on the stream network, locations of gages for calibration, and locations of known point sources. Because SWAT estimates discharge and nutrient loads on a subbasin level within the overall watershed, the SWAT model outputs can be used to identify subbasins with high nutrient loads, which is useful in developing a practicable and targeted implementation plan. The modeling was conducted at the subbasin scale and then aggregated up to larger subwatersheds for the source identification portion of the analysis (Chapter 5).

The SWAT model incorporates data on climate, land cover and land use, soils and topography, and known point sources to simulate hydrology, nutrients (nitrogen and phosphorus), plant growth, and erosion. SWAT allows users to apply watershed-specific information about fertilization practices, grazing practices, irrigation, and septic systems to model nutrient loading from the watershed. The SWAT model also incorporates monitoring data from point sources in the watershed such as the Silver Creek and Coalville City wastewater treatment plants (WWTPs).

In SWAT, hydrology is generated using weather data. Default weather station data are available in SWAT for the United States. However, the model is improved if precipitation and temperature data are provided from weather stations in or near the watershed. Six data stations in and around the watershed were used for the SWAT models developed for Rockport Reservoir and Echo Reservoir watersheds. SWAT also accounts for snowmelt and snowfall effects with snow parameters, and scales precipitation amount and type (snow versus rain) based on elevation. Snow parameters were important in calibrating the timing of the snowmelt in the watershed and subsequent peaks and baseflows. SWAT also uses weather data to estimate evapotranspiration from the watershed.

SWAT generates surface water hydrology using a digital elevation model and weather data from weather stations in or near the watershed. The curve number approach was chosen to estimate runoff volume from the watershed, whereas a modified rational method was used to calculate a peak flow. Groundwater and soil water are also components in the SWAT model, with input tables to adjust those portions of the hydrologic cycle. The USGS gage data and the USGS Baseflow Program algorithms were used to estimate baseflow, which is the contribution of water from groundwater to streams.

Changes in hydrology from human actions are also simulated in SWAT either through its point source feature or as a management operation. In SWAT, a point source is a way to add or subtract flow, sediment, and nutrients to a subbasin from a source that is not included in the land use or soil layers. Additional flow from a WWTP is one example. The Weber-Provo diversion, which removes water from the watershed, is an example of a point source that subtracts flow. Irrigation was also simulated using the management features in SWAT.

Reservoirs can be included in SWAT to simulate the effects of storage and release on the hydrology of the watershed. Only the Smith and Morehouse Reservoir was included in the Rockport Reservoir watershed SWAT model because its effects on flow in the Weber River are important. Rockport Reservoir and Echo Reservoir were intentionally left out because large reservoirs are not well modeled in SWAT for water quality. Instead, reservoir water quality was modeled using BATHTUB.

SWAT models nutrient transport and transformations in the watershed through soil, groundwater, and surface water. SWAT estimates the loads of nitrogen and phosphorus from nonpoint sources described by specific soil and land use combinations (e.g., urban or agricultural runoff) including parameters associated with land management. Management activities include grazing and fertilizer application as well as planting and harvesting of crops. Point sources can represent any type of additional nutrient load. The Rockport Reservoir and Echo Reservoir watersheds include point sources for WWTPs, a fish hatchery, and tunnels carrying stormwater and groundwater to Silver Creek. The point source inputs include loads for organic nitrogen, nitrite, and ammonia as well as mineral and organic forms of phosphorus. SWAT generates output for these nutrient forms on a reach scale.

4.4. Reservoir Model: BATHTUB

The BATHTUB reservoir model was developed by the U.S. Army Corps of Engineers as a sophisticated empirical model for predicting eutrophication in reservoirs. The model predicts nutrient concentrations, chlorophyll *a*, Secchi depth, and other eutrophication indices in a spatially segmented reservoir under steady-state conditions (Walker 1999). Model inputs include reservoir shape (mean depth, length, width, and mixed-layer depth), hydraulic connectivity (between reservoir segments and tributaries), tributary water quality (total nutrients, dissolved nutrients, and flow), climatic parameters (precipitation and evapotranspiration), definition of the stratification season, and atmospheric deposition of nutrients. The model uses empirical equations for physical processes, including advective transport, diffuse transport, and nutrient sedimentation to predict nutrient concentrations and reservoir water quality.

Each set of inputs used specific sources and required individual assumptions which are discussed in detail in Appendix A. The model predicts average water quality in the reservoirs for the defined stratification season. The summer stratified period is the most critical for DO concerns because stratification prevents the mixing of oxygen rich waters at the surface into the lower parts of the reservoir (hypolimnion). Algal growth also occurs during the summer season, the decomposition of which leads to low DO in the hypolimnion. Calibration of the BATHTUB model also requires estimates of reservoir water quality parameters, which are discussed in Appendix A.

4.4.1. Stratification Season

The reservoirs were assumed to be thermally stratified for 137 days from May 15 to September 30. These dates were selected based on evaluation of all temperature and DO profile data available for the reservoirs. Temperature and DO profile data from the years 2004, 2007, and 2011 were used to further validate the use of this stratification season assumption for all of the conditions modeled (see Figures 2.2 through 2.7). These dates were used to determine reservoir elevation at the beginning and ending of stratification using data available from the BOR (2012). Elevations at both reservoirs are significantly lower at the end of the season for 2004 and 2007. In 2007, the water level in Rockport Reservoir began at 1,839.4 m and ended at 1,829.6 m. The year 2011 was wet, and end-of-season elevation was slightly higher than at the beginning for Echo Reservoir and significantly higher for Rockport Reservoir. This is due to flood control measures implemented by Weber Basin Water Conservancy District to draw the reservoirs down before large predicted runoff.

4.4.2. Reservoir Shape and Segmentation

Rockport Reservoir and Echo Reservoir were each divided into a mid-upper pool segment and a dam segment (Figures 4.3 and 4.4). Chalk Creek and Weber River are tributaries to the Echo Reservoir mid-upper pool segment; Weber River is the only tributary to the mid-upper pool for Rockport Reservoir. Tributary inputs for each of the dam segments are based on direct discharge into the reservoirs. Reservoir shape includes seasonal starting and ending elevations; average length, width, and depth; surface area; depth at stratification of mixed layer and hypolimnion; and volume. An updated (2007) bathymetry dataset was available for Rockport Reservoir, but no bathymetry data were available for Echo Reservoir. Depth measurements collected throughout Echo Reservoir in summer 2007 by the Weber Basin Water Conservancy District were used, together with contour data available at the surface of the reservoir, to generate a simplistic bathymetry dataset for purposes of estimating reservoir shape at varying elevations. Spatial analysis tools in ArcGIS, including volumetric estimation, were used to calculate all reservoir dimensions except hypolimnetic depth. Hypolimnetic depth was determined through examination of depth profiles of temperature and DO collected during each year at various times during the stratification season. From these data, the percentage of the total depth that is represented by the hypolimnion and metalimnion was determined for both the mid-upper pool and dam segments.

4.5. Model Results

Modeling results from SWAT were used to determine the total nutrient loads to each reservoir under three conditions (dry, wet, and average). Loads are summarized in the current load section of Chapter 6. The SWAT model was also used to differentiate the sources generated by each nonpoint source at the subwatershed scale, the results of which are presented in Chapter 5. In addition, the SWAT model was used to derive delivery ratios for nitrogen and phosphorus from each subwatershed to the reservoir of interest. Delivery ratios represent nutrient processing between a source and the receiving waterbody. These delivery ratios are incorporated into the load analysis and source identification components of the TMDL (Chapters 5 and 6).

Modeling results from BATHTUB were used to derive water quality targets for the TMDL and to determine the necessary nutrient load reductions for the reservoirs (see Chapter 6). A summary of model calibration and results is also provided in Appendix A.

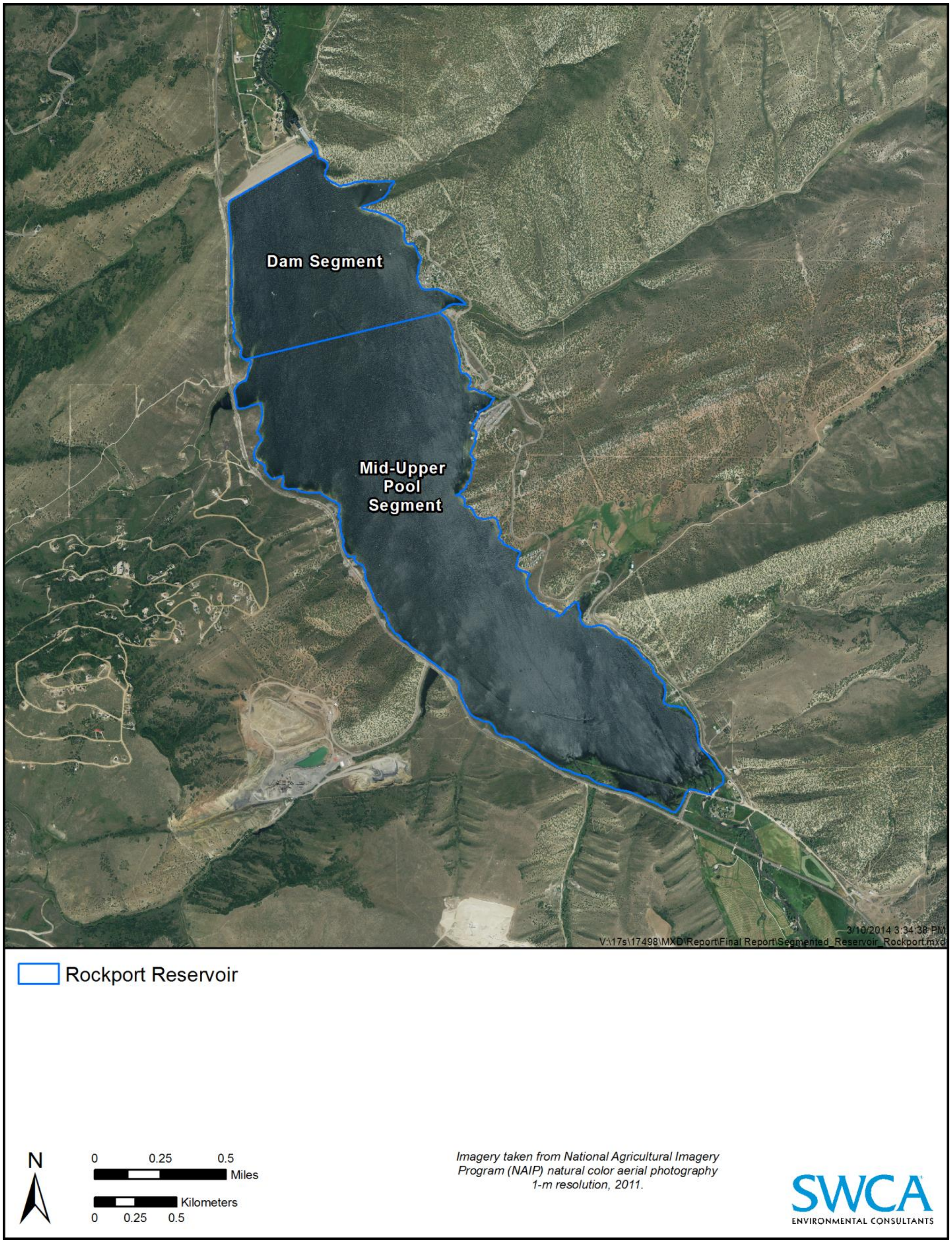

Figure 4.3. Rockport Reservoir model segments.

Figure 4.4. Echo Reservoir model segments.

5. SOURCE IDENTIFICATION

5.1. Summer Season (April–September)

This section discusses nutrient sources that contribute to the DO impairment of Rockport and Echo Reservoirs. The Weber River and its major tributaries Silver Creek, Chalk Creek, and Beaver Creek transport nutrients from point sources and nonpoint sources in the watershed to the reservoirs. The point sources consist of four existing WWTPs, a fish hatchery, and a series of mine tunnels originating in the Park City area. Blue Sky Ranch is a new point source with planned discharge into the watershed. Francis WWTP is an existing non-discharging lagoon system that may convert to a discharging system in the near future. Nonpoint sources of nutrients in the watershed include stormwater runoff, agricultural activities, channel erosion, septic systems, and channel erosion. The Three Mile Canyon Landfill is also known to contribute nitrate to Rockport Reservoir. In addition, releases from Rockport Reservoir represent an upstream load to the Echo Reservoir watershed. Agricultural activities consist of irrigation and fertilizer applications to support crops, crop harvesting, and grazing of sheep and cows. Grazing occurs on public and private land. Contributions from individual nonpoint sources vary throughout the year and by location within the watershed. These sources are difficult to monitor and are not regulated; however, their impacts can be mitigated through best management practices (BMPs), reservoir management, and channel stabilization.

Rockport Reservoir watershed and Echo Reservoir watershed are divided into subwatersheds (Figure 5.1) for purposes of source identification. Characterizing sources at the subwatershed level contributes to a more meaningful implementation plan that is based on prioritization of BMPs for specific sources and areas of the watershed. Characteristics for each subwatershed that illustrate the relative importance of specific sources are summarized in Table 5.1. All of the nutrient loads discussed in this section are seasonal, representing the period of April 1–September 30, the critical period for DO impairment in the reservoirs. Loads are derived based on data and model output for the year 2007, a year that represents an average climatic condition and for which there are sufficient water quality data in the tributaries and reservoirs to develop and calibrate watershed and reservoir water quality models (see Appendix A).

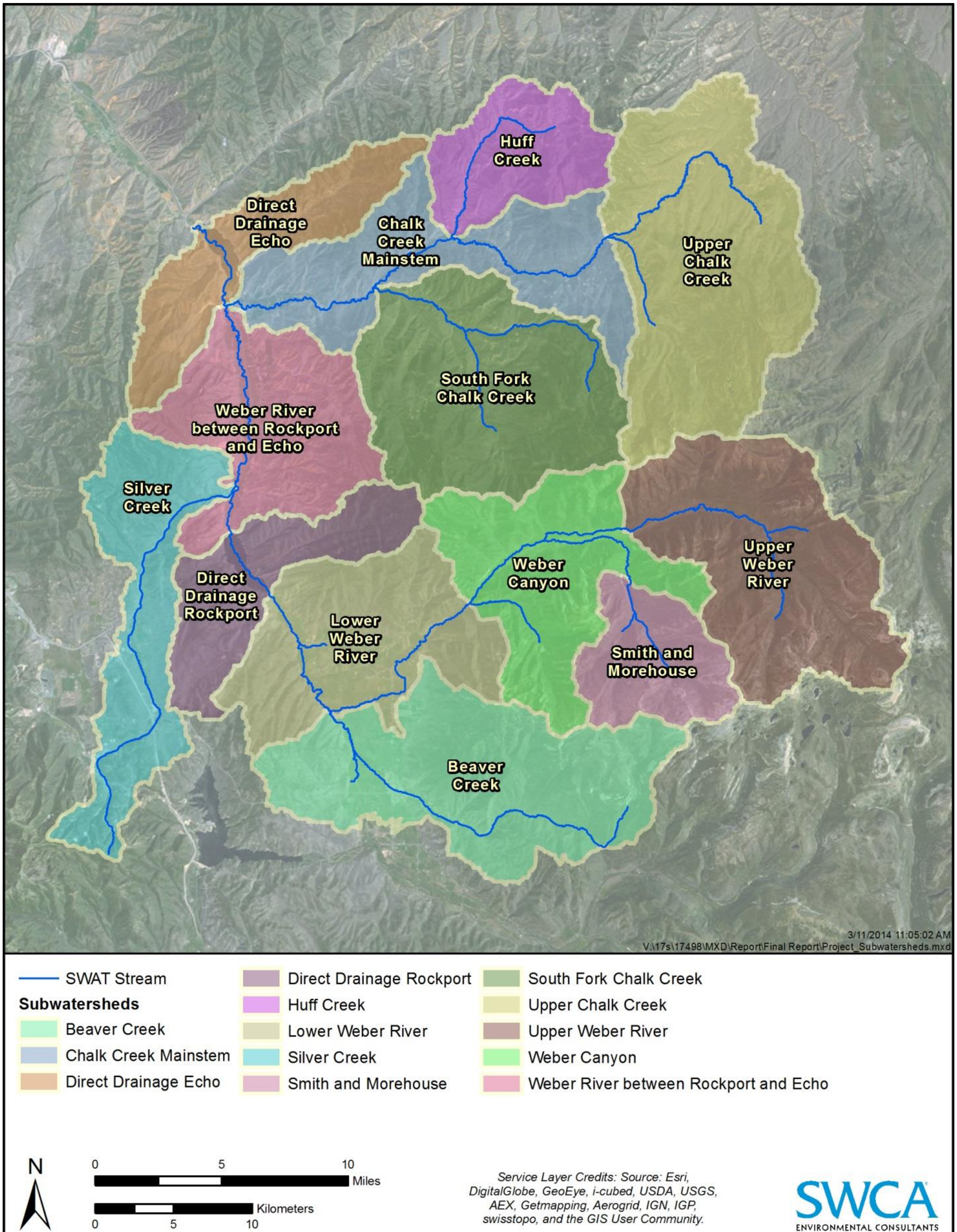

Figure 5.1. Subwatersheds used for source identification and characterization in the Rockport Reservoir watershed and Echo Reservoir watershed.

Table 5.1. Characteristics of Subwatersheds in the Rockport Reservoir and Echo Reservoir Watersheds

Subwatershed	Total Acreage	Percentage Agricultural	Percentage Urban	Percentage Forest, Shrub, and Wetland	Point Sources	Nitrogen Delivery Ratio	Phosphorus Delivery Ratio	TN Load to Reservoir (kg/summer season)	TP Load to Reservoir (kg/summer season)
Rockport Reservoir Watershed									
Beaver Creek	53,549	13.5%	3.9%	82.6%	Kamas WWTP and DWR Kamas Fish Hatchery	79%	83%	2,981	687
Direct Drainage Rockport	22,584	0.5%	5.0%	94.5%	None	100%	100%	2,948	306
Lower Weber River	36,572	21.1%	3.8%	75.2%	Oakley WWTP	100%	100%	3,434	814
Smith and Morehouse	17,627	<0.1%	0.4%	99.6%	None	55%	56%	1,596	126
Upper Weber River	47,514	1.5%	0.4%	98.1%	None	45%	56%	3,453	225
Weber Canyon	34,817	3.5%	3.7%	92.8%	None	67%	56%	4,161	180
Total	**212,663**	**8.0%**	**2.9%**	**89.1%**	**N/A**	**N/A**	**N/A**	**18,573**	**2,337**
Echo Reservoir Watershed									
Chalk Creek Mainstem	36,181	7.9%	2.7%	89.4%	Coalville WWTP	100%	100%	5,440	505
Direct Drainage Echo	23,793	3.8%	2.2%	94.0%	None	100%	100%	384	162
Huff Creek	19,767	1.6%	0.7%	97.8%	None	71%	70%	1,019	260
Silver Creek	32,556	4.1%	25.0%	70.9%	Silver Creek Water Reclamation Facility; Park City tunnels; Blue Sky Ranch	75%	72%	13,775	1,986
South Fork Chalk Creek	47,863	0.6%	0.8%	98.5%	None	84%	84%	2,695	769
Upper Chalk Creek	56,876	0.2%	0.3%	99.5%	None	82%	83%	2,319	46
Weber River between Rockport and Echo	34,186	12.3%	4.3%	83.4%	None	100%	100%	17,077	1,658
Total	**251,222**	**4.0%**	**4.7%**	**91.3%**	**N/A**	**N/A**	**N/A**	**42,709**	**5,387**

5.1.1. Point Sources

Point sources of nutrients have the potential to affect water quality year-round in the Weber River Basin. During periods of low flow, point sources represent a larger portion of the load to streams (Table 5.2). Currently, four municipal WWTPs discharge treated effluent at seven outfalls in the watershed (Figure 5.2). The outfalls discharge nutrients, organic matter, and sediment, among other pollutants commonly found in wastewater, and have the potential to affect DO concentrations. The UPDES program regulates WWTPs and monitors their discharges to ensure compliance with their permit.

The Kamas WWTP and Oakley WWTP discharge in the Rockport Reservoir watershed. The DWR Kamas Fish Hatchery was reopened in November 2012 and is permitted to discharge to the Weber River in the Rockport Reservoir watershed. It is not included in the current load analysis because it was not operating during the time frame that impairments were evaluated nor for the time frame used in the watershed model. Francis WWTP is an existing, non-discharging lagoon system in the Rockport Reservoir watershed that may convert to a discharging system in the near future. The Silver Creek Water Reclamation Facility (WRF) and the Coalville WWTP are in the Echo Reservoir watershed. Park City discharges water from several mine tunnels to Silver Creek in the Echo Reservoir watershed. Currently, the mine tunnels do not have UPDES permits, but the tunnels will be issued permits in the near future. Park City has monitored these sources in the past. Finally, Blue Sky Ranch will treat industrial and municipal wastewater and recently received a permit to discharge to Silver Creek in the Echo Reservoir watershed. The treatment system has not yet been constructed.

Table 5.2. Nutrient Loads from Point Sources in the Rockport Reservoir and Echo Reservoir Watersheds

Subwatershed	Point Source	Load to Receiving Waterbody (kg/season)[1]		Load to Reservoir (kg/season)[2]		Percentage of Load Reaching the Reservoir (delivery ratio)	
		TN	TP	TN	TP	TN	TP
Rockport Reservoir Watershed							
Beaver Creek	Kamas WWTP	1,587	348	1,051	231	66%	66%
	DWR Kamas Fish Hatchery[3]	N/A	N/A	N/A	N/A	69%	70%
	Francis WWTP	N/A	N/A	N/A	N/A	69%	70%
Lower Weber River	Oakley WWTP	1,016	152	703	106	69%	70%
Total	**3**	**2,603**	**500**	**1,754**	**337**	**N/A**	**N/A**

Echo Reservoir Watershed							
Chalk Creek Mainstem	Coalville WWTP	946	193	715	165	76%	86%
Silver Creek	Silver Creek WRF	15,976	1,797	11,343	1,258	71%	70%
	Park City tunnels total	830	67	53	4	6%	6%
	Judge Tunnel	*89*	*6.7*	*5.7*	*0.4*	*6%*	*6%*
	Spiro Tunnel	*620*	*23.8*	*39.6*	*1.5*	*6%*	*6%*
	Prospector Drain/Biocell	*121*	*36.6*	*7.7*	*2.2*	*6%*	*6%*
	Blue Sky Ranch and Resort (future discharge)[4]	N/A	N/A	N/A	N/A	71%	70%
Total	**6**	**17,751**	**2,057**	**12,111**	**1,427**	**N/A**	**N/A**

[1] Calculated based on discharge monitoring report data.

[2] Calculated based on results from SWAT.

[3] Not discharging during modeled period (2007), delivery ratios based on subbasin delivery ratio.

[4] Not currently discharging, delivery ratios based on subbasin delivery ratio.

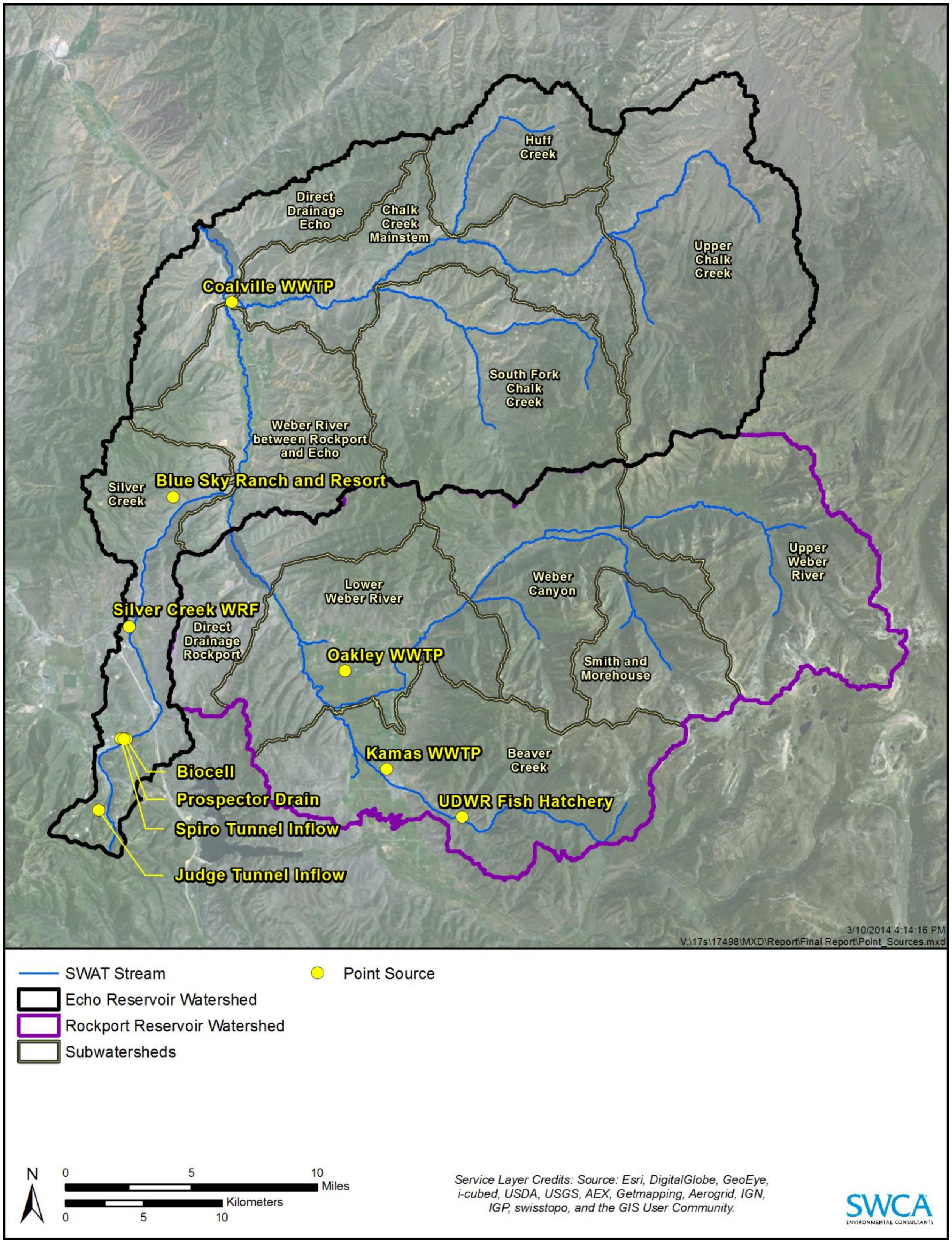

Figure 5.2. Point source outfall locations in the study watershed.

5.1.1.1. ROCKPORT RESERVOIR WATERSHED POINT SOURCES

5.1.1.1.1.Kamas City Wastewater Treatment Plant

The Kamas City WWTP (UPDES UT0020966) serves a population of approximately 1,500 people. The Kamas plant was most recently upgraded in 1991. Current design includes an 18-inch inlet pipe leading to five waste stabilization ponds (the first three of which are aerated), ultraviolet light disinfection, an effluent flow meter, a 10-kilowatt generator, and seven 20-horsepower aerators. The five lagoons cover approximately 18.8 acres. No nutrient data were available for the Kamas plant, except for flow (Table 5.3). Averages used for load calculations were based on input from DWQ (see Appendix A for details). The total average nutrient loads to Beaver Creek are 1,587 kilograms (kg) TN/season and 348 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Rockport Reservoir is 1,051 kg TN/season and 231 kg TP/season.

Table 5.3. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Kamas City Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.17[1]	–	–	–	–	–	–	–
Summer monthly average	0.22[1]	–	–	–	–	–	–	–
Maximum monthly average	0.83[1]	–	–	–	–	–	–	–
Minimum monthly average	0.04[1]	–	–	–	–	–	–	–
Value used for current load calculation	0.14	8.41	2.80	7.60	4.80	16.00	3.51	3.50
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	1,587	N/A	348
Load delivered to Rockport Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	1,051	N/A	231

Note: TKN = total Kjeldhal nitrogen. MGD = million gallons per day.

[1] Based on monthly average data from discharge monitoring reports.

5.1.1.1.2.Oakley City Wastewater Treatment Plant

The Oakley City WWTP (UPDES UT0020061) was designed for daily flows of 0.25 million gallons per day (MGD). The plant processes wastewater using the following methods. First, influent wastewater is run through a 2-millimeter screen followed by compaction and grit removal. Next, wastewater enters an aeration basin and then into a membrane bioreactor for additional filtration. Finally, wastewater is treated using an ultraviolet disinfection system before being discharged into the Weber River.

No nutrient data were available for the Oakley City plant, although flow data was available (Table 5.4). Refer to Appendix A for averages used to calculate seasonal TN and TP loads. The total average nutrient loads to the Lower Weber River are 1,016 kg TN/season and 152 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Rockport Reservoir is 703 kg TN/season and 106 kg TP/season.

Table 5.4. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Oakley City Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.38[1]	–	–	–	–	–	–	–
Summer monthly average	0.29[1]	–	–	–	–	–	–	–
Maximum monthly average	0.96[1]	–	–	–	–	–	–	–
Minimum monthly average	0.07[1]	–	–	–	–	–	–	–
Value used for current load calculation	0.15	5.25	1.75	4.75	3.00	10.00	1.50	1.50
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	1,016	N/A	152
Load delivered to Rockport Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	703	N/A	106

Note: TKN = total Kjeldhal nitrogen.

[1] Based on monthly average data from discharge monitoring reports.

5.1.1.1.3. DWR Kamas Fish Hatchery

The DWR operates a fish hatchery near Kamas that discharges to Beaver Creek. A UPDES general permit regulates these discharges. The hatchery was rebuilt in 2000, but has operated only intermittently over the last 10 years. The recent closure in 2010 was related to whirling disease (personal communication, Wes Pearce, DWR, and Andrew Myers, SWCA, September 18, 2013); however, the hatchery reopened in November 2012 and is currently operating. The hatchery operates as a flow-through system, and discharges range from 2.13 to 4.47 MGD between April and September according to discharge monitoring report data. BMPs to reduce nutrient loads in the effluent were implemented in 2003 (personal communication, Lonnie Shull, UDEQ, and Erica Gaddis, SWCA, July 19, 2013). The nutrient loads discharged are estimated to be 177 kg TP/season and 1,162 kg TN/season. Rockport Reservoir receives 69%–70% of the load discharged to Beaver Creek. The facility is not expected to expand and therefore the nutrient loads discharged should remain at existing levels.

5.1.1.1.4.Town of Francis Wastewater

The Town of Francis (UPDES UTOP00202) currently manages wastewater in a lagoon system without discharging to surface waters. Francis is currently discussing the possibility of expanding the wastewater treatment system, which could include discharging to the Weber River. Such a system would operate at an average daily flow of 0.14 MGD with the potential to expand to 0.36 MGD by 2035. Based on current wastewater characterization data, the total phosphorus concentration in the influent is 7 mg/L. Total Nitrogen estimates were not available but current ammonia-N concentrations in the influent are 25 mg/L (Carollo Engineers 2012).

5.1.1.2. ECHO RESERVOIR WATERSHED POINT SOURCES

5.1.1.2.1.Coalville City Corporation Wastewater Plant

The Coalville City Corporation WWTP (UPDES UT0021288) serves a population of approximately 1,470 people. It was originally designed as a trickling filter plant in 1964. Since then, three upgrades have been completed. First, in 1985, the plant was modified to an extended aeration/activated sludge plant. Subsequent additions include two biosolids drying beds in 1992, the addition of a Somat screw press for dewatering, a composting pad, and alterations to existing drying beds in 1995. Plant design allows for an average daily flow of 0.35 MGD and peak flow of 0.42 MGD. Coalville City is currently in the process of moving the WWTP. The newly designed WWTP accounts for growth through 2035. Monthly data were available for flow, ammonia, and TP (Table 5.6). Weekly and instantaneous data were used to generate average values for nitrate + nitrite and total Kjeldhal nitrogen (TKN). Organic N was calculated by subtracting ammonia from TKN, and TN was calculated as the sum of TKN and nitrate + nitrite. All of the TP was assumed to be in dissolved form. The total average nutrient loads to Chalk Creek are 946 kg TN/season and 193 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 715 kg TN/season and 165 kg TP/season.

Construction is currently underway on a new WWTP in Coalville, UT. The new facility will use activated sludge treatment technology with nutrient removal based on a Modified Ludzack-Ettinger (MLE) process. The new facility will have potential design limits for treating TN and TP to less than 10 mg/l and less than 1.0 mg/l, respectively, as required by the DWQ. Wastewater treatment will occur in two 0.3 mgd process trains for a total maximum monthly treatment of 0.6 mgd. The new facility is expected to complete and online by February 2015.

Table 5.6. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Coalville City Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.20[1]	5.53[2]	0.44[1]	1.34[2]	0.90[3]	6.87[3]	–	0.87[1]
Summer monthly average	0.21[1]	5.22[2]	0.46[1]	1.29[2]	0.83[3]	6.51[3]	–	0.90[1]
Maximum monthly average	0.30[1]	10.35[2]	1.70[1]	4.00[2]	2.30[3]	14.35[3]	–	1.80[1]
Minimum monthly average	0.15[1]	2.20[2]	0.40[1]	1.00[2]	0.60[3]	3.20[3]	–	0.10[1]
Value used for current load calculation	0.21	5.22	0.40	1.09	0.69	6.31	1.39	1.39
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	946	N/A	193
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	715	N/A	165

Note: TKN = total Kjeldhal nitrogen.

[1] Based on monthly average data from discharge monitoring reports.

[2] Based on 7-day average and/or instantaneous values.

[3] Calculated.

5.1.1.2.2. Silver Creek Water Reclamation Facility

The Snyderville Basin Water Reclamation District operates the Silver Creek WRF (UPDES UT0024414), a conventional, secondary treatment plant that services residential areas and permitted significant industrial users in portions of the watershed, including areas of Park City. Constituents with specific effluent limitations are DO, BOD, total suspended solids, ammonia, *E. coli*, oil and grease, and pH (UPDES UT0024414). Phosphorus is not regulated with a specific effluent limitation, but is sampled on a monthly basis under the existing permit, which is currently in the process of being renewed. No flow is indicated in the UPDES permit, but the current facility has a capacity of 2.0 MGD and average monthly summer flow is 1.23 MGD. Upgrades are currently being planned, with final designs based on a discharge of 4.0 MGD. The designs and technology included in the upgrades depend in part on the effluent concentrations identified in the UPDES permit.

Monthly data were available for flow, ammonia, and TP (Table 5.7). Weekly and instantaneous data were used to generate average values for nitrate + nitrite, TKN, and dissolved P. Organic N was calculated by subtracting ammonia from TKN, and TN was calculated as the sum of TKN and nitrate + nitrite. The total average nutrient loads to Silver Creek are 15,976 kg TN/season and 1,797 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 11,343 kg TN/season and 1,258 kg TP/season.

Table 5.7. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Silver Creek Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	1.21[1]	17.14[2]	0.33[1]	1.57[2]	1.24[3]	18.71[3]	2.28[2]	2.51[1]
Summer monthly average	1.23[1]	16.19[2]	0.21[1]	1.43[2]	1.22[3]	17.62[3]	2.09[2]	2.14[1]
Maximum monthly average	2.00[1]	21.68[2]	1.71[1]	2.60[2]	0.89[3]	24.28[3]	3.42[2]	4.20[1]
Minimum monthly average	0.56[1]	8.35[2]	0.30[1]	1.00[2]	0.98[3]	9.35[3]	1.03[2]	1.10[1]
Value used for current load calculation	1.23	17.49	0.22	1.42	1.20	18.90	2.12	2.12
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	15,976	N/A	1,797
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	11,343	N/A	1,258

Note: TKN = total Kjeldhal nitrogen.

[1] Based on monthly average data from discharge monitoring reports.

[2] Based on 7-day average and/or instantaneous values.

[3] Calculated.

5.1.1.2.3.Judge Tunnel

Judge Tunnel (UPDES UT0025925) carries groundwater from a series of mine tunnels to a chlorination vault where the flow is treated and becomes drinking water for Park City (see Figure 5.2). If the turbidity is too high the water bypasses the vault and is released into Empire Creek, a tributary to Silver Creek (Park City Municipal Corporation 2013). Judge Tunnel's average monthly flow is somewhat variable, but generally small compared to mainstem flows. The average monthly discharge is 0.4 cfs. The state will be issuing a UPDES permit for Judge Tunnel to regulate discharges from the tunnel.

Instantaneous data were used to generate average values for flow, nitrite + nitrate, and TP (Table 5.8). It was assumed that all of the phosphorus was in the dissolved form. The total average nutrient loads to Silver Creek are 89 kg TN/season and 7 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 6 kg TN/season and 0 kg TP/season.

Table 5.8. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Judge Tunnel from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.41	0.13	–	–	–	–	–	0.04
Summer monthly average	0.52	0.17	–	–	–	–	–	0.03
Maximum monthly average	4.40	0.30	–	–	–	–	–	0.05
Minimum monthly average	–	0.01	–	–	–	–	–	0.02
Value used for current load calculation	0.52	0.13	0.09[1]	–	0.30[1]	0.52[1]	0.04[2]	0.04
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	89	N/A	7
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	6	N/A	0

Note: TKN = total Kjeldhal nitrogen.

[1] Based on data from Spiro Tunnel.

5.1.1.2.4.Spiro Tunnel

Like Judge Tunnel, Spiro Tunnel (UPDES UT0025941) collects groundwater from mine tunnels (Figure 5.3). Spiro Tunnel discharges water into two irrigation ditches in the Silver Creek watershed: 1) the Bates, Snyder, Dority Ditch and 2) the Pace Homer Ditch. Spiro Tunnel discharges directly into Silver Creek at the Pace Homer Ditch (Park City Municipal Corporation 2013). Spiro Tunnel average discharge is approximately 1.5 cfs.

Instantaneous data were used to generate average values for flow, nitrite + nitrate, dissolved P, and TP (Table 5.9). Organic N was calculated by subtracting ammonia from TKN, and TN was calculated as the sum of TKN and nitrate + nitrite. Only one data sample was available for ammonia and TKN, taken in October. The total average nutrient loads to Silver Creek are 620 kg TN/season and 24 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 40 kg TN/season and 1 kg TP/season.

Table 5.9. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Silver Spiro Tunnel from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	1.50	0.12	0.10	0.40	0.30[1]	0.52[1]	0.02	0.02
Summer monthly average	2.30	0.14	–	–	–	–	0.02	0.03
Maximum monthly average	3.90	0.20	0.10	0.40	0.30[1]	0.52[1]	0.03	0.03
Minimum monthly average	0.03	0.01	0.10	0.40	0.30[1]	0.52[1]	0.01	0.02
Value used for current load calculation	2.30	0.12	0.10	–	0.30	0.52	0.02	0.02
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	620	N/A	24
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	40	N/A	1

[1] Calculated.

5.1.1.2.5.Prospector Drain and Biocell

Prospector Drain collects shallow groundwater impacted by mine tailings. This drain also collected stormwater until 2012 when Park City eliminated cross-connection from stormwater sources.

A portion of flow from Prospector Drain goes into the biocell, which treats the water for metal contamination. The biocell contains organic matter in the form of manure, which may explain the high nutrient concentrations in the biocell discharge, which goes to Silver Creek. The remaining water in Prospector Drain flows untreated to Silver Creek (Park City Municipal Corporation 2012). These sources contribute a relatively small quantity of flow to Silver Creek. The Prospector Drain discharges an estimated 0.07 cfs, and the biocell may contribute 0.04 cfs.

The biocell and Prospector Drain are expected to be part of an EPA-directed Comprehensive Environmental Response, Compensation, and Liability Act removal action in the foreseeable future. The discharges from these sources will be addressed, pending EPA approval of a removal action. Therefore, no UPDES permit will be issued for these point sources until the EPA-directed removal action is complete (Park City Municipal Corporation 2013).

Instantaneous data were used to generate average values for flow, nitrite + nitrate, and TP (Table 5.10). It was assumed that all of the phosphorus was in the dissolved form. The total average nutrient loads to Silver Creek from Prospector Drain and the biocell combined are 121 kg TN/season and 37 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the combined total load delivered to Echo Reservoir is 8 kg TN/season and 2 kg TP/season

Table 5.10. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Prospector Drain and Biocell from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Prospector Drain								
Monthly average	0.07	3.03	–	–	–	–	–	0.06
Summer monthly average	0.07	3.32	–	–	–	–	–	–
Maximum monthly average	0.22	4.60	–	–	–	–	–	–
Minimum monthly average	0.03	1.50	–	–	–	–	–	–
Value used for current load calculation	0.07	3.03	0.10[1]	0.10[1]	0	4.00	0.06	0.06
Biocell								
Monthly average	0.04	0.09	–	–	–	–	–	2.29
Summer monthly average	0.04	0.08	–	–	–	–	–	0.61
Maximum monthly average	0.06	0.30	–	–	–	–	–	28.30
Minimum monthly average	0.01	0.01	–	–	–	–	–	0.08
Value used for current load calculation	0.04	0.08	0.10[1]	0.90[2]	1.00[2]	1.20	2.30	2.30
Prospector Drain and Biocell								
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	121	N/A	37
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	8	N/A	2

[1] Based on background in Silver Creek.

[2] Based on typical concentration of TKN in high phosphorous effluents.

5.1.1.2.6.Blue Sky Ranch and Resort

Blue Sky Ranch and Resort is a proposed resort development in the lower part of the Silver Creek watershed. The state has issued a UPDES discharge permit (UT0025763) for the on-site WWTP, designed to treat 30,000 gallons per day. This WWTP is not yet operational and has no discharge. When the development is complete, the plant will discharge directly into Alexander Creek, a tributary to Silver Creek. Under the permit, Blue Sky Ranch and Resort will receive offsets for phosphorus because the developers plan to remove all cattle grazing on the property. The Blue Sky Ranch and Resort WWTP will be allowed to discharge 0.03 MGD with 1.0 mg/L TP, reflecting the phosphorus offset, and 1.0 mg/L total ammonia as N as monthly averages. Based on this design the total seasonal load would be 21 kg TP/season and 208 kg TN/season.

5.1.2.Nonpoint Sources

5.1.2.1. STORMWATER

Residential and commercial development has increased the amount of impervious surface area (roads, parking lots, etc.) in the Rockport and Echo Reservoir watersheds, which contributes to an increase in stormwater runoff (Figure 5.3). Figure 5.4 shows a number of outfalls in Park City. Additional outfalls likely exist in the watershed, but have not been mapped. Stormwater transports nutrients that have accumulated on surfaces during dry periods. The runoff generally begins as diffuse flow (e.g., off a parking lot), which is then directed to curb and gutters and storm drains. These drains direct stormwater into canals and other drainages, where it eventually reaches a stream. There is usually no treatment associated with stormwater unless BMPs are installed and maintained. Stormwater can be problematic at active construction sites because of sediment loading. Construction in areas with soils of severe erosion potential underlain by a rock formation with elevated phosphorus concentrations may generate excess loads of phosphorus if proper BMPs are not used.

Because of its more rural nature, stormwater generates a smaller nutrient load in the Rockport Reservoir watershed compared to the Echo Reservoir watershed. Stormwater in the Rockport Reservoir watershed generates 278 kg TP/season and 601 kg TN/season. Within the Rockport Reservoir watershed, the Direct Drainage subwatershed contains the highest percentage of impervious cover and generates the highest loads from stormwater, 123 kg TP/season 226 kg TN/season. The Lower Weber River, Weber Canyon, and Beaver Creek subwatersheds are similar in the amount of development that has occurred and they generate similar amounts of nutrient loads from stormwater, 42–54 kg TP/season and 106–130 kg TN/season. The subwatersheds with the least amount of impervious surface—Upper Weber River and Smith and Morehouse subwatersheds—are higher in the drainage and generate very little nutrient load from stormwater. These subwatersheds generate less than 10 kg TP/season and 20 or less kg TN/season (Table 5.11).

The Echo Reservoir watershed contains areas that have seen increased urbanization in the last decade, including portions of Park City as well as the I-80 corridor and US-40 corridor. Stormwater accounts for 683 kg TP/season and 933 kg TN/season to the Echo Reservoir. The Silver Creek subwatershed contributes the most load in the Echo Reservoir watershed (413 kg TP/season and 522 kg TN/season). It contains nearly 5% impervious cover, and 25% of the subwatershed is low to medium density development. The I-80 and US-40 road corridors are also primarily within the Silver Creek subwatershed. Chalk Creek contributes 93 kg TP/season and 95 kg TN/season, reflecting the development of 2.7% of the watershed and the 0.4% impervious cover. Upper Chalk Creek generates the least stormwater, having the least amount of development and impervious cover (Table 5.11).

The acreages from the land use datasets were used to calculate the percentage of low- to medium-density development and the percentage of high-density development and roads. The percentage of impervious cover was calculated using proportions of low-, medium-, and high-density development that would be impervious cover provided in the SWAT databases.

Table 5.11. Summary of Stormwater Related Subwatershed Characteristics and Loads to Reservoirs

Subwatershed	Total Acres	TP Load[1] (kg/season)	TN Load[1] (kg/season)	Low- to Medium-Density Development (% of watershed)	High-Density Development and Roads (% of watershed)	Impervious Cover (% of subwatershed)
Rockport Reservoir Watershed						
Beaver Creek	53,549	47	106	3.9%	<0.1%	0.7%
Direct Drainage Rockport	22,584	123	226	5.0%	<0.1%	0.8%
Lower Weber River	36,572	54	130	3.8%	<0.1%	0.7%
Smith and Morehouse	17,627	3	4	0.4%	<0.1%	0.1%
Upper Weber River	47,514	9	20	0.4%	<0.1%	0.1%
Weber Canyon	34,817	42	115	3.7%	<0.1%	0.7%
Total	**212,663**	**278**	**601**	**2.9%**	<0.1%	**0.5%**
Echo Reservoir Watershed						
Chalk Creek Mainstem	36,181	93	95	2.7%	<0.1%	0.4%
Direct Drainage Echo	23,793	58	99	2.2%	0.2%	0.3%
Huff Creek	19,767	26	27	0.7%	<0.1%	0.1%
Silver Creek	32,556	413	522	25.0%	0.7%	4.7%
South Fork Chalk Creek	47,863	37	42	0.8%	<0.1%	0.1%
Upper Chalk Creek	56,876	5	18	0.3%	<0.1%	<0.1%
Weber River between Rockport and Echo	34,186	51	130	4.3%	0.4%	0.8%
Total	**251,222**	**683**	**933**	**4.7%**	**0.2%**	**0.8%**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

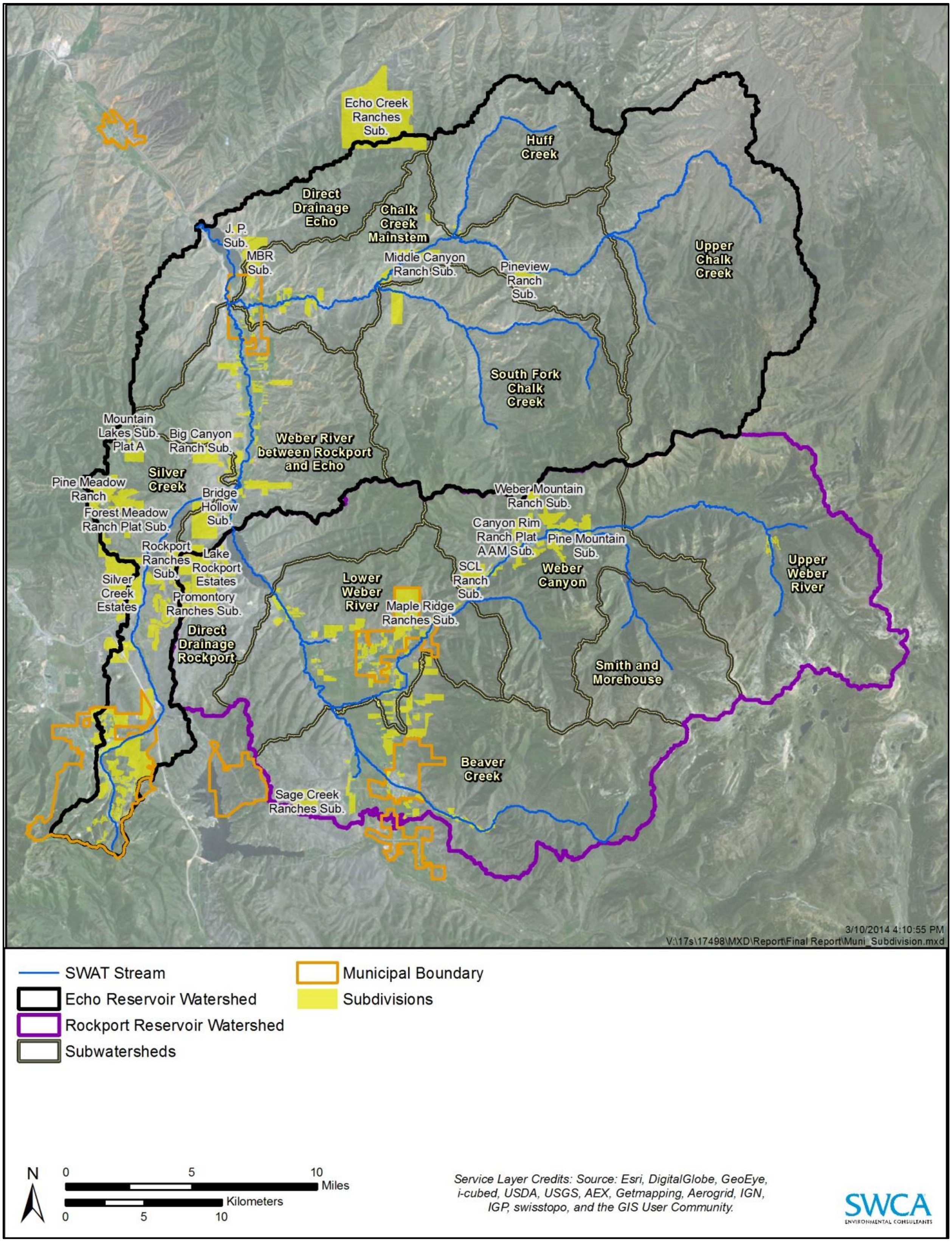

Figure 5.3 Municipalities and subdivisions in the study watershed.

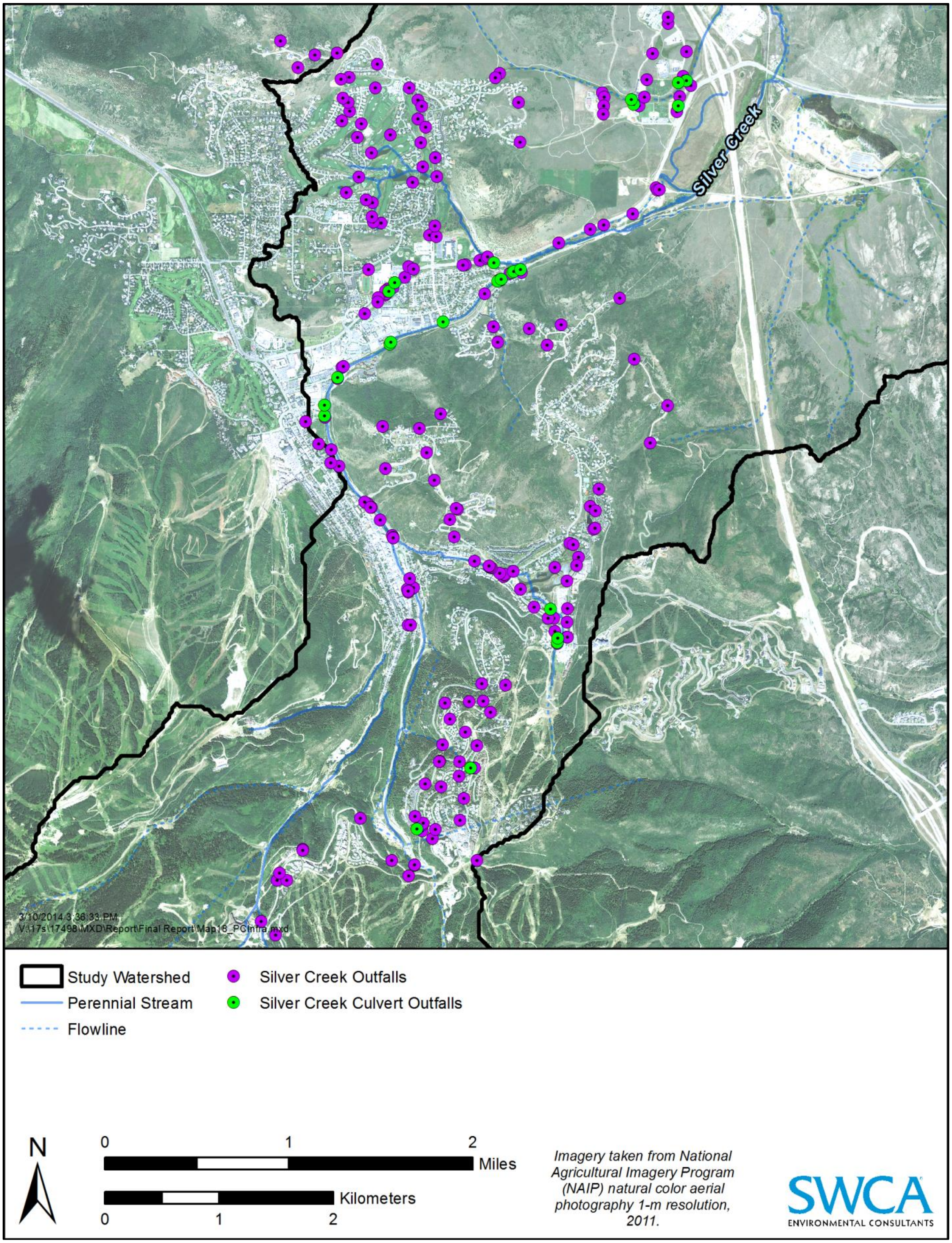

Figure 5.4 Locations of stormwater outfalls in the Silver Creek subwatershed.

5.1.2.2. AGRICULTURAL SOURCES

Grazing, hay, and alfalfa production, as well as other crop production are examples of agricultural activities that occur in the Rockport and Echo Reservoir watersheds (Figure 5.5). These activities involve use of fertilizers and irrigation in some areas of the watersheds. Agriculture is considered a nonpoint source, and it generates sediment and nutrients through active grazing, application of fertilizers, and irrigation.

In the Rockport Reservoir watershed, agricultural activities generate 1,235 kg TP/season and 8,166 kg TN/season. Grazing occurs on up to 56% of the total watershed area, depending on the season and individual operations, whereas crops occur on 2% of the watershed area. The Lower Weber River subwatershed generates the highest phosphorus load from agricultural activities in the Rockport Reservoir watershed (553 kg TP/season). In this subwatershed, 33% of the land may be used for private grazing, and over 7% is used to cultivate crops. Weber Canyon and Upper Weber contribute the highest nitrogen load (2,167 and 2,132 kg TN/season respectively). Although 47% of the area in the Beaver Creek subwatershed is used for public grazing and 20% for private grazing, it generates a smaller nutrient load (322 kg TP/season and 848 kg TN/season). Agricultural activities in this subwatershed consist primarily of grazing on public lands (Table 5.12).

Agricultural activities in the Echo Reservoir watershed generate 965 kg TP/season and 13,019 kg TN/season. The “Weber River between Rockport and Echo” subwatershed contributes the most TP from agriculture to Echo Reservoir (276 kg/season). Huff Creek accounts for 125 kg TP/season, whereas Silver Creek contributes 270 kg TP/season. The “Weber River between Rockport and Echo” subwatershed generates 4,973 kg TN/season, almost 40% of the TN load from agriculture in the Echo Reservoir watershed. The Chalk Creek Mainstem contributes high amounts of TN as well (3,465 kg/season). Direct drainage to Echo Reservoir accounts for approximately 60 kg TN/season. No public grazing allotments are present in the Echo Reservoir watershed, but private grazing occurs in each subwatershed. Crop cultivation, if present, occurs on less than 5% of the subwatershed area.

The percentage of subwatershed within public grazing allotments was calculated assuming that USFS lands identified as an allotment within the subwatershed were grazed. The Smith and Morehouse allotment is not currently an active allotment and, although included in the area percentage, is not included in load calculations. The percentage of watershed coinciding with private grazing-land uses is assumed to be proportional to the acreage of forest, pasture, and range that is privately owned. The percentage of watershed as crop is calculated as the proportion of subwatershed area that is identified as agriculture, alfalfa, hay, or orchard on the land use map.

Table 5.12. Summary of Agricultural-Related Subwatershed Characteristics and Loads to Reservoirs

Subwatershed	Total Acres	Percentage of Subwatershed within Public Grazing Allotments	Percentage of Watershed Coinciding with Private Grazing Land Uses	Percentage of Watershed as Crop	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Rockport Reservoir Watershed						
Beaver Creek	53,549	47%	20%	2.9%	323	848
Direct Drainage Rockport	22,584	0%	20%	<0.1%	147	746
Lower Weber River	36,572	7%	33%	7.2%	553	1,077
Smith and Morehouse	17,627	100%[2]	0%	<0.1%	73	1,195
Upper Weber River	47,514	25%	20%	0.2%	86	2,132
Weber Canyon	34,817	46%	13%	0.1%	54	2,167
Total	**212,663**	**35%**	**21%**	**2.1%**	**1,235**	**8,165**
Echo Reservoir Watershed						
Chalk Creek Mainstem	36,181	0%	34%	2.24%	92	3,465
Direct Drainage Echo	23,793	0%	24%	3.39%	76	61
Huff Creek	19,767	0%	34%	<0.1%	125	568
Silver Creek	32,556	0%	32%	0.44%	270	1,309
South Fork Chalk Creek	47,863	0%	41%	<0.1%	115	1,078
Upper Chalk Creek	56,876	<0.1%	55%	<0.1%	11	1,565
Weber River between Rockport and Echo	34,186	0%	29%	3.73%	276	4,973
Total	**251,222**	**<1%**	**38%**	1.2%	**965**	**13,019**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

[2] The Smith and Morehouse allotment is not currently active; however it was active during the 2007 modeled season and loads have been allocated for future use of this allotment.

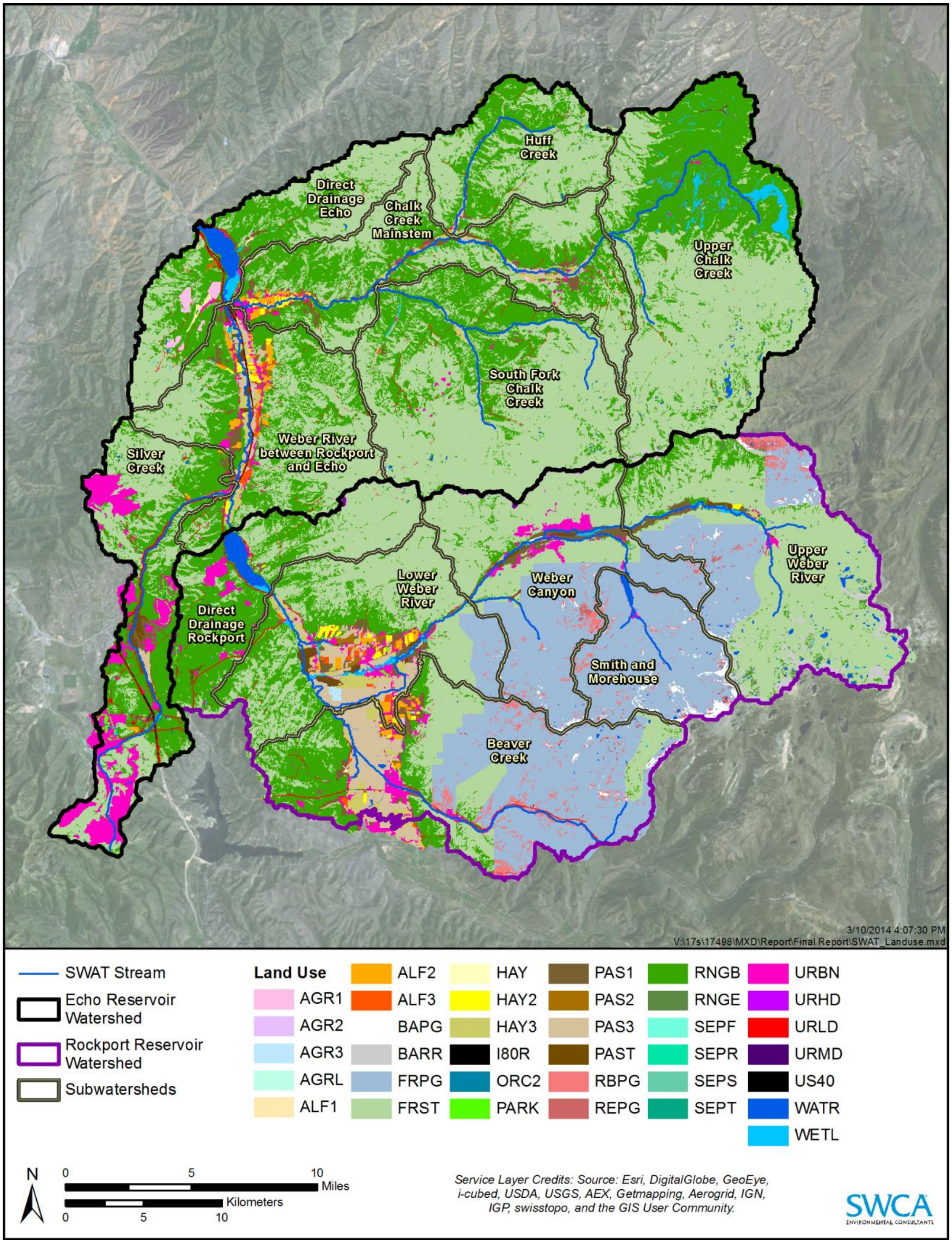

Figure 5.5. Land use by subwatershed in Rockport Reservoir and Echo Reservoir watersheds.

Note: The light blue areas dominating Rockport Reservoir watershed represent public grazing allotments, whereas privately owned areas potentially grazed are PAS1-PAST, FRST, RNGB, and RNGE. Crops are considered AGRL, AGR1-3, ALFA, ALF1-3, and HAY-HAY3.

5.1.2.2.1.Grazing on Public Land

Five USFS allotments occur in the study watershed (see Figure 5.6). Among benefits such as clean water, wildlife protection, recreation, and others, "forage for livestock" on public forest land is protected under the Multiple Use Sustained-Yield Act of 1960 (Swank 1998). It is important to note that a) allotments do not coincide with subwatershed boundaries and may only be partially contained in a watershed and b) cattle are not dispersed evenly across the landscape. Allotment data were used to estimate the number of livestock that graze within the watershed (Table 5.13). USFS allotments are exclusively high-elevation, with use restricted to the summer season. Cattle graze on USFS land primarily in July, August, and September, although some grazing occurs as early as June and as late as October. Generally, cattle that graze on public lands are pastured on private lands in the valley during the rest of the year.

Table 5.13. Identified Grazing Permits on USFS Lands in Rockport Reservoir and Echo Reservoir Watersheds

Allotment Name	Allotment Area in Watershed (acres)	Typical Dates	Average Animals in Watershed (acres)	Animal Type
Rockport Reservoir Watershed				
Humpy Creek	973	July 25–September 24	382	Ewe/lamb pairs
Kamas Valley	25,299	June 10–October 15	336	Cows
Moffit	2,747	July 11–September 29	1,048	Ewe/lamb pairs
Weber River	28,975	June 21–September 30	186	Cows
Total	**57,994**		**1,952**	
Echo Reservoir Watershed				
Humpy Creek	5	July 25–September 24	2	Ewe/lamb pairs
Total	**5**		**2**	

5.1.2.2.2.Grazing on Private Land

Rangeland and pasturelands in the watershed are typically adjacent to local streams. Cattle within a grazed pasture rarely spread out and cover the entire acreage evenly; rather, they tend to congregate around areas where water is readily available (riparian areas and stream channels) and forage is plentiful. Consequently, a greater proportion of the manure is deposited in or nearby stream channels and riparian areas, resulting in a greater potential for direct transport of nutrients and pathogens.

Grazing within the watershed occurs on public USFS-managed allotments as well as on private land. Employees from the NRCS at the Coalville office supplied information on private grazing, including estimates of the animal units by season in the watershed zones (Figure 5.6) for both Rockport Reservoir and Echo Reservoir watersheds.

Typically, cattle graze in the valleys in the fall and spring. In the hot summer months, they are taken to the higher elevation forests, and in the winter, they are relocated to the West Desert. Table 5.14 provides the estimated number of cattle grazing seasonally on private lands in the study watershed. For the Weber River watershed, cattle density is greatest during summer and fall seasons. The Beaver Creek subwatershed is the exception; here, approximately 2,000 cattle graze year-round.

Table 5.14. Number of Grazing Cattle per Season on Private Land

NRCS Zone	Spring (March 21–June 21)	Summer (June 22–September 21)	Fall (September 22–December 22)	Winter (December 23–March 21)
Rockport Reservoir Watershed				
Beaver Creek	2,000	2,000	2,000	2,000
Weber River between Rockport and Weber-Provo Diversion	1,000	1,500	1,500	1,000
Weber River Canyon	1,000	3,000	1,500	500
Total	**4,000**	**6,500**	**5,000**	**3,500**
Echo Reservoir Watershed				
Chalk Creek	500	3,500	3,500	500
Silver Creek	100	1,100	500	100
Weber River between Echo and Rockport	1,500	1,500	2,500	1,500
Total	**2,100**	**6,100**	**6,500**	**2,100**

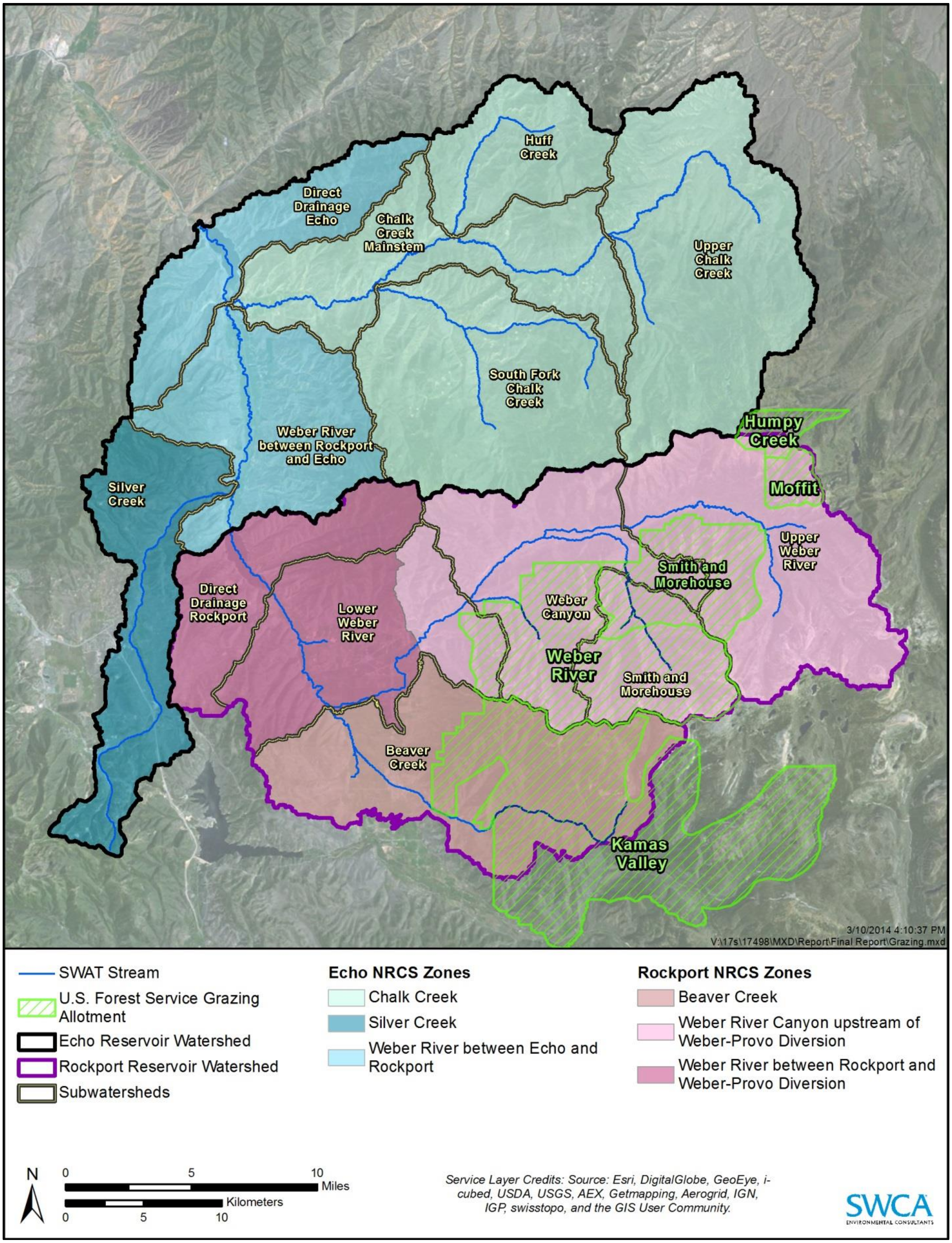

Figure 5.6. Zones used to broadly quantify the number of grazing animals on private property (NRCS zones) and the locations of USFS allotments in the Rockport Reservoir and Echo Reservoir watersheds.

5.1.2.2.3.Fertilizer and Manure Application

Fertilizer and manure are applied to fields to improve crop yields on agricultural lands. Fertilizer is also used in urban areas, generally on lawns, landscaping, and turf on golf courses and recreational sports fields. Applied fertilizer may wash off during storm events or during irrigation, particularly flood irrigation. Water flowing off fields may drain directly back to the stream or to irrigation or drainage ditches. Runoff from urban landscapes directly adjacent to a stream may transport fertilizer directly to that stream. For example, a stream may run through a golf course that has been landscaped to the stream banks. Storm drains may also conduct flow off urban areas and transport fertilizer to streams.

The NRCS provided broad estimates of fertilizer application types and rates for the entire watershed. They indicated that most of the fertilizer used in both the Rockport Reservoir and Echo Reservoir watersheds is a commercial type with 11:52:11 (N:P:K) applied at a rate of 35 kg/year. Areas within 1 mile of a dairy operation were assumed to use manure in place of commercial fertilizers, using the same application rate. Urban areas are likely to be fertilized to keep grass and turf alive, but they are also likely to be more water efficient. These areas were assigned a lower application rate of 5kg/hectare. It was assumed fertilizer was not applied to high-density urban areas.

Nutrient loads from fertilizer application are included in the total loads from agriculture described in section 5.1.2.2. The characteristics of fertilizer application will affect the amount of nutrients washed off, with surface runoff generated by storm events, spring runoff, or irrigation return flow. In the Rockport Reservoir watershed, the Lower Weber River subwatershed contains the highest percentage of fertilized area, with agricultural and urban areas being fertilized. Beaver Creek fertilizer application is about half that of the Lower Weber River watershed, whereas essentially no fertilizer application occurs in the Smith and Morehouse subwatershed. In the Upper Weber River and Weber Canyon subwatersheds, fertilizer application occurs mostly in urban areas, with little application to agricultural areas (Table 5.15).

Table 5.15. Fertilizer Characteristics

Subwatershed	Total Acres	Percentage of Watershed Fertilized	Acres of Fertilized Agricultural Areas (using 35 kg/ha)	Acres of Fertilized Urban Areas (using 5 kg/ha)
Rockport Reservoir Watershed				
Beaver Creek	53,549	6.0%	1,575	1,566
Direct Drainage Rockport	22,584	3.0%	10	654
Lower Weber River	36,572	11.0%	2,640	1,238
Smith and Morehouse	17,627	0.3%	0	49
Upper Weber River	47,514	0.5%	80	153
Weber Canyon	34,817	2.0%	40	746
Total	**212,663**	**4.0%**	**4,345**	**4,407**
Echo Reservoir Watershed				
Chalk Creek Mainstem	36,181	5.7%	1,263	816
Direct Drainage Echo	23,793	4.5%	754	311
Huff Creek	19,767	1.0%	105	100
Silver Creek	32,556	14.3%	143	4,516
South Fork Chalk Creek	47,863	1.0%	155	319
Upper Chalk Creek	56,876	0.2%	0	125
Weber River between Rockport and Echo	34,186	9.5%	2,063	1,187
Total	**251,222**	**5.0%**	**4,483**	**7,375**

5.1.2.2.4.Irrigation Return Flow

Irrigation return flow is runoff from agricultural fields (such as pasture and hay fields) that is generated by irrigating the field. The runoff either returns to the irrigation ditch or the stream directly down-gradient from the field. Irrigation return flow is primarily associated with flood irrigation practices and less so with sprinkler irrigation. Flood irrigation allows water to flow from a ditch or stream onto the fields directly through a head gate or other diverting works. This method effectively flushes soil, biomass, manure, and fertilizer off the field and into the ditch or stream. Sprinkler systems apply less water at rates that allow water to infiltrate the soil, thereby reducing irrigation return flow generated from surface runoff.

Over-irrigation of pasture and hayland will also raise the water table and lead to changes in the mobility of phosphorus in soils. Phosphorus has been observed to move more easily through soils that are consistently waterlogged because most of the iron present in these soils is reduced, and sorption potential is decreased (Sharpley 1995). Waterlogged soils are also prone to the loss and transport of fine, lightweight soil particles (such as silt and clay) to receiving waters. These fine particles represent the primary phosphorus sorption sites in the soil. These particles carry a significant amount of phosphorus with them when they are removed and leave the remaining soil deficient in phosphorus holding capacity (Hedley et al. 1995). Nitrogen is highly mobile in soils, and over-irrigation would promote leaching through the soil layers. Return flow also easily transports nitrogen to irrigation canals and streams from irrigated fields.

Flood irrigation efficiency was assumed to be 30%, and sprinkler irrigation was assumed to be 70%. The surface runoff was assumed to be 40% from flood-irrigated land and 5% for sprinkler-irrigated lands (personal communication, Thomas Hoskins, NRCS, and Erica Gaddis, SWCA, December 12, 2012). These values reflect the difference in the amount and quality of irrigation return flow generated from flood irrigation compared to sprinkler irrigation.

Nutrient loads from irrigation return flows are included with the total loads from agriculture . Irrigation methods will affect the quantity of nutrients transported by irrigation return flow. Sprinkler irrigation generates less return flow; compared to flood irrigation, it transports less fertilizer, sediment, and other debris from agricultural fields that contain nutrients. Based on the Water Related Land Use data, flood irrigation is the primary form of irrigation in the Rockport Reservoir watershed. Sprinkler and flood irrigation are almost equivalent in Echo Reservoir watershed, with flood irrigation being slightly higher.

In the Rockport Reservoir watershed, 5.6% of the total area is irrigated, primarily with flood irrigation. Sprinkler irrigation is applied to 2,102 acres across the Rockport Reservoir watershed. The Lower Weber River subwatershed has the highest proportion of irrigated land (16%). In this subwatershed, 1,383 acres are sprinkler irrigated and 4,799 acres are flood irrigated. Irrigation occurs on 10% of the Beaver Creek subwatershed, with nearly 5,000 acres as flood irrigation and only 656 acres irrigated with sprinklers. Very little irrigation occurs in the Weber Canyon subwatershed, and no irrigation occurs in the Smith and Morehouse subwatershed (Table 5.16; Figure 5.7).

Irrigation occurs on 3% of the Echo Reservoir watershed, with sprinkler irrigation occurring on 2,467 acres and 3,672 acres being flood irrigated. Irrigation occurs on almost 10% of the Weber-River-between-Rockport-and-Echo subwatershed. In this subwatershed, 1,185 acres are sprinkler irrigated and 1,947 acres are flood irrigated. No irrigation occurs in the Upper Chalk Creek subwatershed. In Silver Creek and the Direct Drainage Echo subwatershed, sprinkler irrigation occurs on more acreage than does flood irrigation. Most irrigation in the South Fork Chalk Creek subwatershed is under flood irrigation (Table 5.16; Figure 5.7).

Table 5.16. Irrigation Return Flow

Subwatershed	Total Acres	Percentage of Subwatershed Irrigated	Acres with Sprinkler Irrigation	Acres with Flood Irrigation
Rockport Reservoir Watershed				
Beaver Creek	53,549	10.5%	656	4,960
Direct Drainage Rockport	22,584	<0.1%	12	1
Lower Weber River	36,572	16.9%	1,383	4,799
Smith and Morehouse	17,627	<0.1%	0	0
Upper Weber River	47,514	0.2%	45	35
Weber Canyon	34,817	0.1%	5	29
Total	**212,663**	5.6%	**2,102**	**9,823**
Echo Reservoir Watershed				
Chalk Creek Mainstem	36,181	5.8%	906	1,182
Direct Drainage Echo	23,793	0.3%	54	28
Huff Creek	19,767	1.0%	11	192
Silver Creek	32,556	1.2%	310	89
South Fork Chalk Creek	47,863	<0.1%	1	234
Upper Chalk Creek	56,876	0%	0	0
Weber River between Rockport and Echo	34,186	9.16%	1,185	1,947
Total	**251,222**	**3.0%**	**2,467**	**3,672**

Note: At least 100 acres of land in the South Fork subwatershed have been converted to sprinkler irrigation since the publishing of the water-related land use data upon which this table is based.

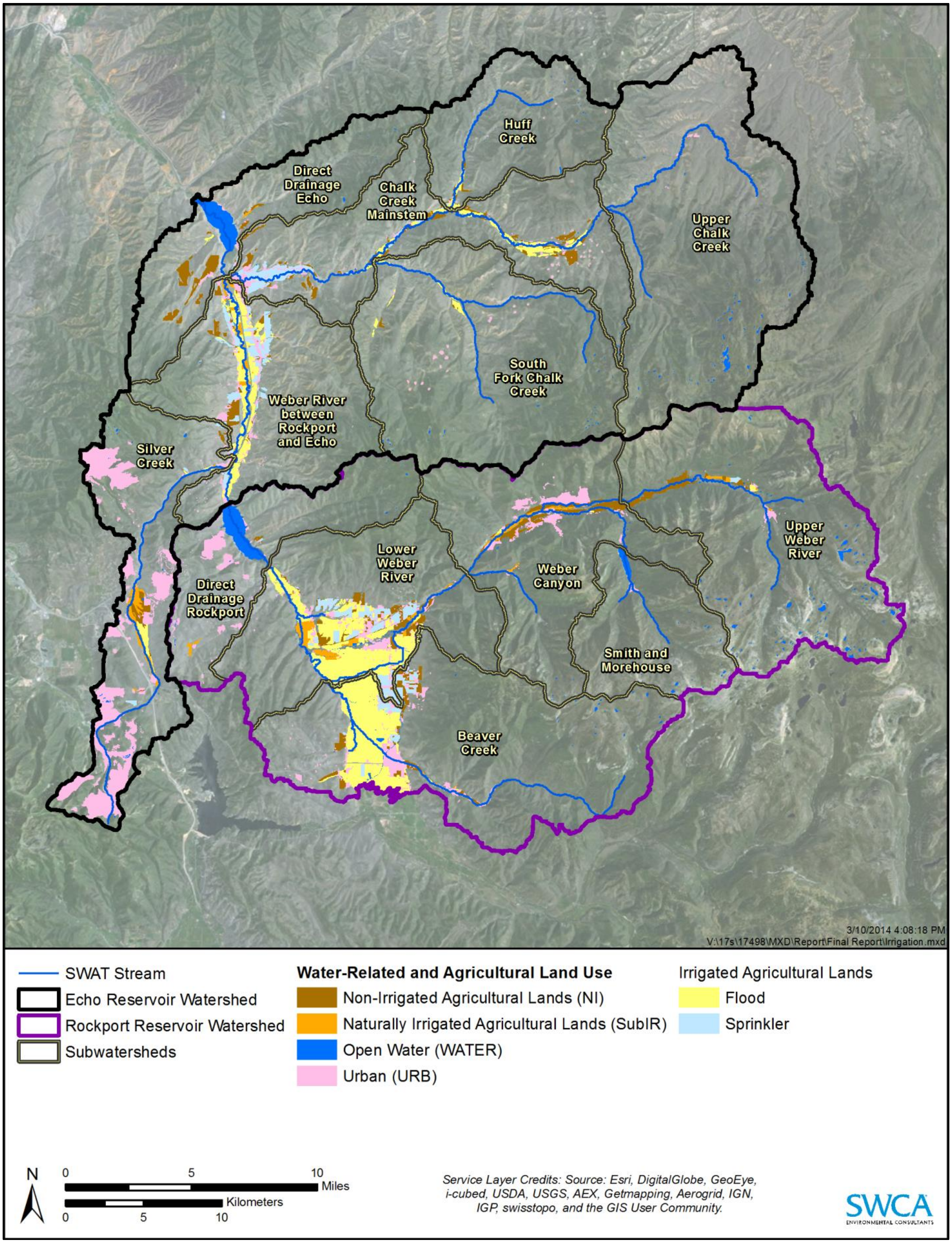

Figure 5.7. Areas of sprinkler and flood-irrigated lands in each subwatershed.

5.1.2.3. SEPTIC SYSTEMS

Although the WWTPs discussed above serve a large portion of the Rockport Reservoir and Echo Reservoir watersheds, there are an estimated 3,764 septic systems in the study watershed (Table 5.17; Figure 5.8). Septic system failure, improper design, and poor location of a leach field can increase the nutrient loads and BOD from these systems. A properly operating septic system treats wastewater and disposes of the water through an underground leach field. Soils beneath the leach field remove most pathogens by filtering, adsorption, and biological processes. However, where soils or groundwater conditions are marginally suitable, or where septic densities are too high, conventional septic systems fail and removal rates are reduced or no treatment occurs at all. A septic system can affect surface waters when soils below the leach field become clogged or flooded and when effluent reaches the surface where it can be washed off into a stream. An associated problem occurs when a septic system is flooded by groundwater or the depth-to-groundwater is near the base of the leach field and effluent is released to shallow groundwater, which discharges into nearby streams. Therefore, the proximity of septic systems to surface waters (Table 5.17) and the type and depth of the system (Table 5.18) are important factors that have the potential to affect water quality. Additionally, based on early discussions with Summit County Health Department, an EPA-recommended septic system failure rate of 10% was used as a model assumption (EPA 2000). However, it should be noted that this estimate is most likely high for the county (personal communication, Richard Bullough (SCHD), and Erica Gaddis (SWCA), January 13, 2014).

Septic systems have been categorized based on their level of use. The Primary category contains buildings known to be primary residences and other buildings that are likely operating all year. Buildings listed as other or unknown, including those identified as Farmland Assessment Act buildings, were included in the Primary category to maintain a conservative estimate of septic systems and their operations within the watershed. Secondary septic systems are based on a county classification of the residence of 6 months or less. Buildings that the county considers recreational have less than 3 months of occupancy over the year.

Table 5.17. Number of Septic Tanks for Primary Residences, Secondary Residences, and Recreational Residences by Subwatershed

Subwatershed	Primary	Secondary	Recreational	Distance to Water (m)	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Rockport Reservoir Watershed						
Beaver Creek	414	41	50	114	18	450
Direct Drainage Rockport	50	13	50	268	2	779
Lower Weber River	400	43	26	110	20	544
Upper Weber River	27	–	75	98	6	509
Weber Canyon	92	10	779	173	34	1,214
Total	**983**	**107**	**980**	**146**	**79**	**3,496**
Echo Reservoir Watershed						
Chalk Creek Mainstem	162	6	2	95	5	199
Direct Drainage Echo	6	–	21	192	0	44
Huff Creek	8	1	–	98	0	2
Silver Creek	212	40	310	189	4	302
South Fork Chalk Creek	6	–	–	47	1	6
Upper Chalk Creek	2	–	–	63	–	1

Table 5.17. Number of Septic Tanks for Primary Residences, Secondary Residences, and Recreational Residences by Subwatershed

Subwatershed	Primary	Secondary	Recreational	Distance to Water (m)	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Weber River between Rockport and Echo	394	24	–	133	10	539
Total	**790**	**71**	**333**	**154**	**19**	**1,093**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

Septic systems contribute 79 kg TP/season and 3,496 kg TN/season to Rockport Reservoir. The Weber Canyon subwatershed contributes the largest nutrients load from septic systems (34 kg TP/season and 1,214 kg TN /season). The Weber Canyon subwatershed contains 779 recreational septic systems and only 92 primary septic systems. The Lower Weber River subwatershed and the Beaver Creek subwatershed contribute just over 100 kg TP/season and 450–500 kg TN/season. These subwatersheds have over 400 primary septic systems and fewer than 100 recreational septic systems. The Direct Drainage subwatershed contributes 779 kg TN/season and only 2 kg TP/season. There are fewer than 200 septic systems in the subwatershed, and most are far from a waterbody. However, most are deep trench septic systems (Table 5.18).

Septic systems contribute 19 kg TP/season and 1,093 kg TN/season to Echo Reservoir. The Weber-River-between-Rockport-and-Echo subwatershed contributes the most nutrients, accounting for about half (10 kg/season) of the TP and almost half (539 kg/season) of the TN load with mostly primary septic systems. The Silver Creek subwatershed, with 212 primary septic systems and 310 recreational septic systems, contributes 4 kg TP/season and 302 kg TN/season. Upper Chalk Creek contains almost no septic systems and does not contribute to nutrient loads from septic systems (Table 5.17).

Table 5.18. Number of Septic Systems by Type and Depth

Subwatershed	Chamber	Deep Trench	Seepage Pit	Shallow
Rockport Reservoir Watershed				
Beaver Creek	15	109	1	69
Direct Drainage Rockport	–	48	–	9
Lower Weber River	7	69	–	61
Upper Weber River	2	15	–	25
Weber Canyon	4	271	1	29
Total	**28**	**512**	**2**	**193**
Echo Reservoir Watershed				
Chalk Creek Mainstem	–	32	–	11
Direct Drainage Echo	–	2	–	3
Huff Creek	–	1	–	–
Silver Creek	10	205	3	34
South Fork Chalk Creek	1	–	–	–
Upper Chalk Creek	–	–	–	–

Table 5.18. Number of Septic Systems by Type and Depth

Subwatershed	Chamber	Deep Trench	Seepage Pit	Shallow
Weber River between Rockport and Echo	2	103	1	41
Total	**13**	**343**	**4**	**89**

[1] Within the study watershed, fewer than five systems of the following types occur: 50 trench, 750 trench, chamber/shallow, drainfield, infiltrated-deep, infiltrated-shallow, and shallow-infiltrated.

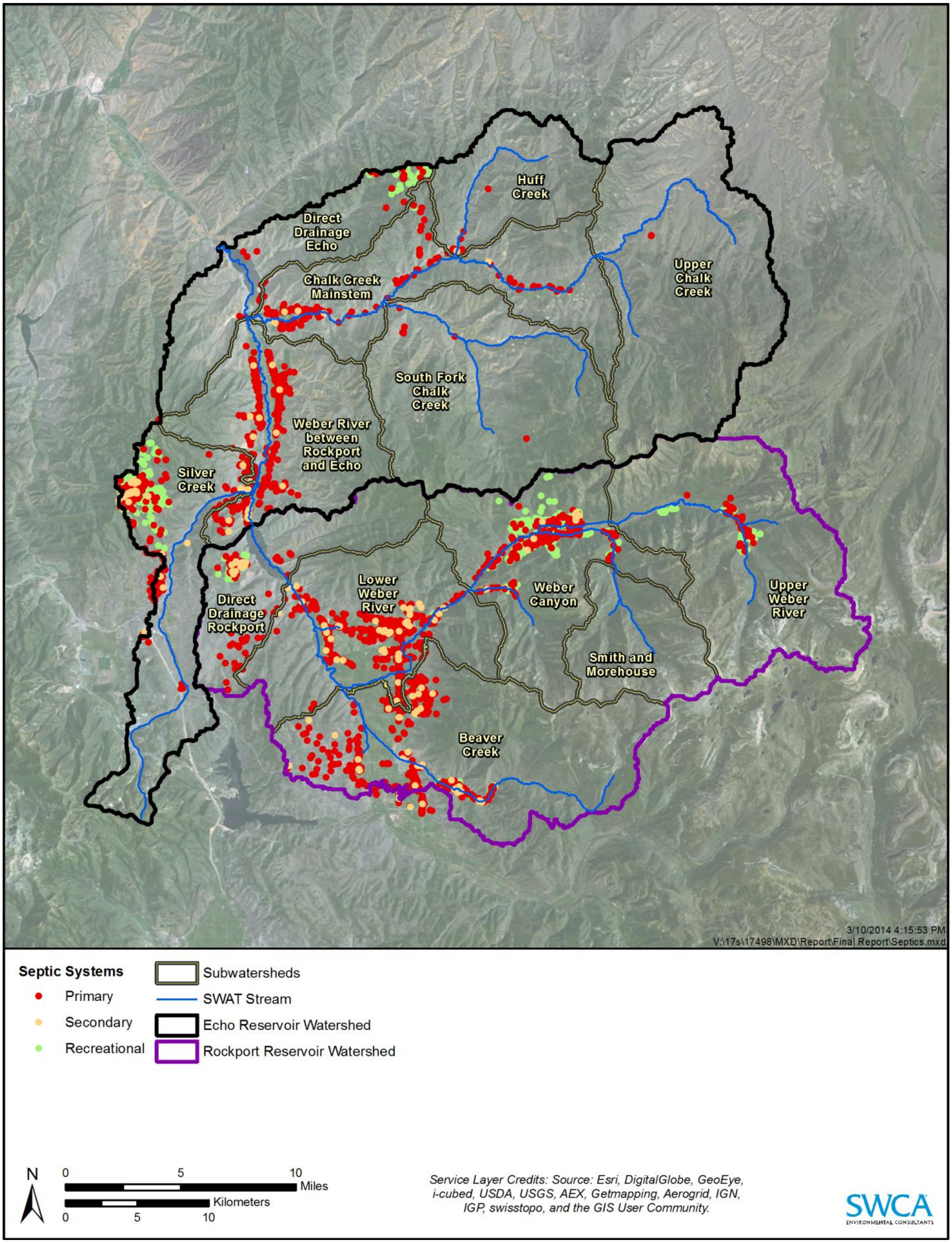

Figure 5.8. Location of septic systems in each subwatershed.

5.1.2.4. STREAMBANK EROSION

Population growth has led to a rise in development in the watershed. The increase in impermeable surface area associated with residential and commercial development in the watershed can result in flashy peak flows that contribute to streambank erosion and inputs of organic matter, nitrogen, and phosphorus to receiving waters. Figure 5.9 shows an example of streambank erosion occurring in the watershed. Sources of sediment and pollutants include stormwater runoff from paved areas, erosion from construction sites, and sediment and nutrients from roads and livestock. Ski areas, golf courses, and livestock grazing also contribute to the potential of increased runoff and the transport of nutrients and sediment as discussed previously. Developments bordering streams have resulted in the removal and disruption of riparian vegetation, and peak storm flows have caused stream down cutting in some areas and widening in others (Bell et al. 2004). This portion of the total load is associated with the increase in channel erosion beyond natural background. The nutrient load from channel erosion is considered negligible in the Rockport Reservoir watershed. In the Echo Reservoir watershed, channel erosion is generally negligible except for South Fork Chalk Creek and "Weber River between Rockport and Echo" subwatersheds (Table 5.21 and Table 5.22).

Figure 5.9. Streambank erosion occurring in the South Fork Chalk Creek subwatershed.

5.1.2.5. THREE MILE CANYON LANDFILL

The Three Mile Canyon Landfill, operated by Summit County, is 600 m west and up-gradient of the Rockport Reservoir. The unlined landfill has been in operation since the late 1980s and collects non-hazardous solid waste from municipal, commercial, industrial, and construction/demolition sources. Groundwater well data are available for one well up-gradient of the landfill and two wells down-gradient of the landfill. Nitrate concentrations up-gradient of the landfill are typically below detection limits (<0.01 mg/L). Nitrate concentrations down-gradient of the landfill range from 1 to 44 mg/L. This increase indicates that landfill leachate is a significant source of nitrate to groundwater. Given the proximity of the landfill to Rockport Reservoir, there is a high probability that some of the groundwater with high nitrogen concentrations is delivered to the reservoir by subsurface flow. Data on groundwater flow into the reservoir are not available. Therefore, SWAT model estimates of groundwater flow were used to estimate a nitrogen load from the landfill that is transported through groundwater. The proportion of the total groundwater flow in the Direct Drainage subwatershed that flows beneath the landfill was assumed to be 1% of the total groundwater flow to the reservoir. This value was calibrated as part of the reservoir modeling to account for a missing nitrogen source that was indicated by reservoir nitrogen data but not by tributary data. The average nitrate concentrations were assumed to be 25 mg/L, based on data collected in 2007, the year used for model calibration. The total estimated nitrate load from the landfill to Rockport Reservoir is 922 kg/season; however, it should be noted that this estimate is considered conservative.

5.1.2.6. NATURAL BACKGROUND

Background loads represent what would exist in the stream without human interaction in the watershed. The soils and geology of the watershed contribute to the natural or background nutrient loads to the Weber River and its tributaries through soil and bedrock erosion and weathering. Most of the watershed consists of a loam-type soil (Figure 5.10). Soils rated as having severe erosion hazard cover most of the watershed and are generally located in steeply sloped areas (see Figure 3.5). A phosphatic shale layer with concentrations of rock phosphorus between 0.04% and 1.19% (Figure 5.11) is also present in the watershed. The areas of higher concentrations coincide with some areas of severe erosion hazard, indicating potential for higher natural phosphorus concentrations, particularly from easily eroded areas. These areas of higher phosphorus include Chalk Creek. Terrestrial and aquatic wildlife also contribute to the natural background load of nutrients.

Some limestone and sandstone formations are present in parts of the watershed, particularly the Silver Creek subwatershed. These rock types are commonly associated with karst topography. The sinkholes that developed in 1982 and 2008 along Silver Creek occurred close to each other in a limestone formation (Loughlin Water Associates, LLC. 2009). Although such formations do not contribute phosphorus, they will affect the total streamflow, thereby affecting the total nutrient load reaching a reservoir.

Dust particles in the atmosphere can contribute phosphorus loads to the landscape and directly to waterbodies, although the amount depends on long-term climatic and short-term weather patterns and therefore varies greatly from year to year.

Natural background load accounts for 409 kg TP/season and 3,634 kg TN/season in Rockport Reservoir watershed. The Upper Weber subwatershed generates the highest natural background load of phosphorus, whereas the Lower Weber generates the highest nitrogen load (Table 5.19). In the Echo Reservoir watershed, background loads contribute 670 kg TP/season and 3,902 kg TN/season. The Weber-River-between-Rockport-and-Echo subwatershed generates the most background load (297 kg TP/season and 958 kg TN/season). The Direct Drainage subwatershed generates the least background load (28 kg TP/season and 180 kg TN/season).

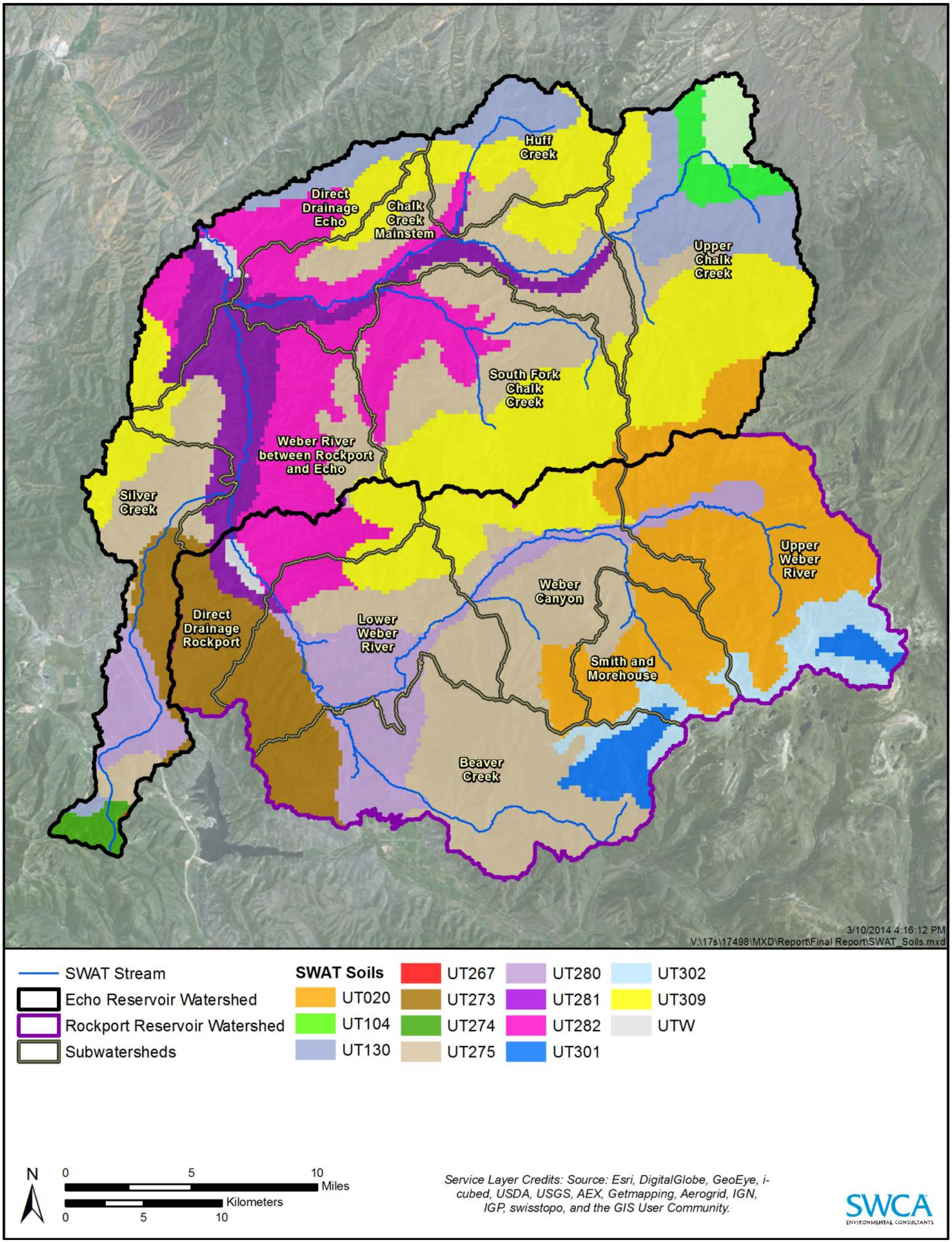

Figure 5.10. Soil types in each subwatershed.

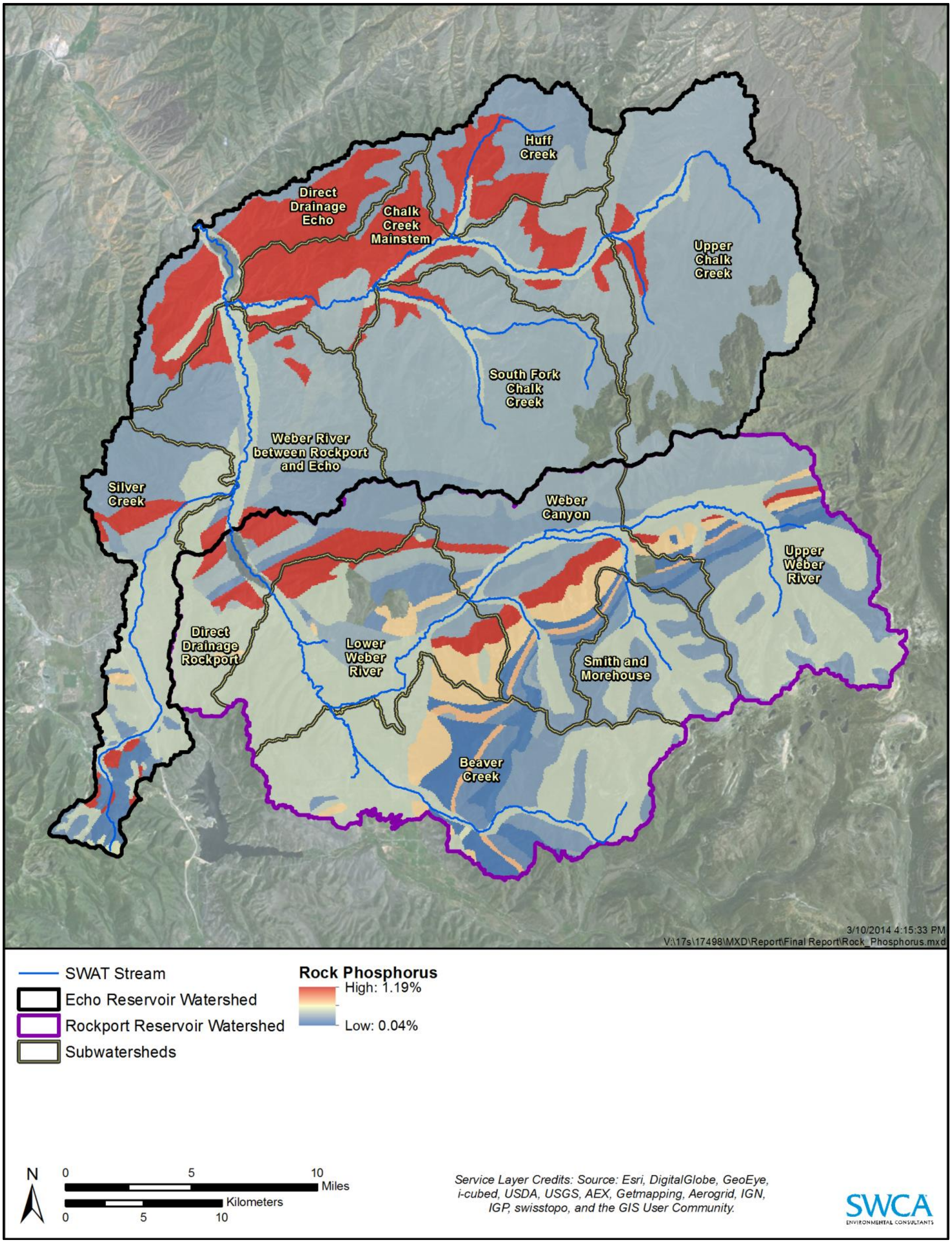

Figure 5.11. Rock phosphorus percentage in each subwatershed.

The natural background nutrient loads were calculated using measured flows from USGS data for all subwatersheds except for the Direct Drainage subwatershed in the Echo Reservoir watershed. Those flows were calculated using SWAT-generated inflow estimates. Values for background concentrations of TN and TP were taken from the EPA reference conditions for level III, ecoregion 9 (EPA 2000). The aggregate values for spring and summer at the 25th percentile were used for TP. The values classified as the 25th percentile for all seasons were used for TN because of a lack of data to generate aggregate values. The total amount of natural background load is tied to the size of the subwatershed and the flows generated in the subwatershed.

Table 5.19. Natural Background Nutrient Loads by Subwatershed

Subwatershed	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Rockport Reservoir Watershed		
Beaver Creek	69	526
Direct Drainage Rockport	34	275
Lower Weber River	81	979
Smith and Morehouse	51	397
Upper Weber River	124	792
Weber Canyon	50	665
Total	**409**	**3,634**
Echo Reservoir Watershed		
Chalk Creek Mainstem	150	966
Direct Drainage Echo	28	180
Huff Creek	38	245
Silver Creek	37	246
South Fork Chalk Creek	89	572
Upper Chalk Creek	30	735
Weber River between Rockport and Echo	297	958
Total	**669**	**3,902**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

5.1.3. Internal Load

Internal pollutant loads are an important consideration when attempting to reverse the eutrophication of lakes. While some lakes may respond rapidly to reductions in external loading of phosphorus, other lakes may experience a delay in recovery due to internal phosphorus loading. This is because the phosphorus in the bottom sediment needs time to equilibrate with the new loading level (Sondergaard et al. 2003; Wetzel 2001). Furthermore, the hypoxic (low oxygen) conditions that occur in the hypolimnion (see Figure 1.1) of stratified lakes can cause phosphorus bound to iron and other elements to be released into the water column (Nurnberg 2009; Sorrano et al. 1997). Therefore, in some stratified lakes internal loading of phosphorus can represent a significant phosphorus load in late summer and early fall. Decomposition of organic matter on the bottom also releases phosphorus in lakes and reservoirs.

Reservoir TP mass balances were calculated for both Rockport and Echo Reservoirs for the years 2004, 2007, and 2011 (Table 5.20). Both reservoirs exhibited similar seasonal trends in TP mass balances as well: in the springtime, both reservoirs were net retainers of TP (more in than out), whereas in the summer, Echo Reservoir maintained its status as a net sink and Rockport became a small net exporter of TP during 2007 only. The small load released from sediments in the summer primarily originates as a spring load; therefore, to avoid double counting, it was not counted as an additional load. Internal nutrient cycling in BATHTUB is incorporated into the empirical equations used in the model as well as in the calibration of parameters. The model calibrated well, with no net internal load included in the model. This confirms that measured tributary loads are good predictors of nutrient concentrations in the reservoirs. Therefore, internal load has not been included as an important source in the source identification for either reservoir.

Table 5.20. Reservoir Internal Load Estimates for Spring and Summer Seasons (kg/season)

	2004	2007	2011
Rockport Reservoir			
In	3,229	2,337	15,190
Out	1,694	2,375	8,297
Net Internal Load (Out – In)	-1,535	38	-6,893
Echo Reservoir			
In	5,099	7,436	26,559
Out	2,124	2,206	12,639
Net Internal Load (Out – In)	-2,975	-5,230	-13,920

5.1.4. Summer (April–September) Season Source Summary

The average TP and TN loads to Echo Reservoir are 5,387 kg/season and 42,709 kg/season, respectively (Tables 5.20 and 5.21). Point sources represent approximately 26% of the TP load and 28% of the TN load into Echo Reservoir (Figures 5.12 and 5.13). Releases from Rockport Reservoir make up 17% of the TP load and 23% of the TN load. Background sources account for 12% of the TP and 9% of the TN load to Echo Reservoir. Stormwater, agricultural sources, and channel erosion are all significant sources of nonpoint sources in the Echo Reservoir watershed for phosphorus. Agricultural nonpoint sources comprise the largest nonpoint source in the watershed for nitrogen. In total, nonpoint sources (excluding background sources and releases from Rockport Reservoir) account for 44% of the TP load and 40% of the TN load to Echo Reservoir.

The TP and TN loads to Rockport Reservoir are 2,337 kg/season and 18,573 kg/season, respectively (Tables 5.20 and 5.21). Point sources represent approximately 14% of the TP load and 9% of the TN load into Rockport Reservoir (Figures 5.14 and 5.15). Background sources account for 18% of the TP and 20% of the TN load to Echo Reservoir. Agricultural nonpoint sources comprise the largest nonpoint source in the watershed for both nitrogen and phosphorus. Stormwater is also a significant source of both nutrients to Rockport Reservoir. The landfill and septic systems, primarily in Weber Canyon and the Lower Weber subwatersheds, are also significant sources of nitrogen to Rockport Reservoir. In total, nonpoint sources (excluding background sources) account for 68% of the TP load and 71% of the TN load to Rockport Reservoir.

Table 5.21. Summary of Nonpoint Source Total Phosphorous Loads (kg per summer season [April–September])

Subwatershed	Stormwater	Private Grazing	Irrigation/ Fertilizer	Public Grazing	Septic Systems	Channel Erosion	Natural Background	Upstream	Total Nonpoint Source	Point Source Load	Total
Rockport Reservoir Watershed											
Beaver Creek	47	144	129	50	18	0	69	0	456	231	687
Direct Drainage Rockport	123	147	–	–	2	0	34	0	306	–	306
Lower Weber River	54	306	221	26	20	0	81	0	708	106	814
Smith and Morehouse	3	–	–	73	–	0	51	0	126	–	126
Upper Weber River	9	64	–	22	6	0	124	0	225	0	225
Weber Canyon	42	28	–	26	34	0	50	0	180	0	180
Total	**278**	**688**	**350**	**196**	**79**	**0**	**409**	**0**	**2,000**	**337**	**2,337**
Echo Reservoir Watershed											
Chalk Creek Mainstem	93	74	18	–	5	0	150	0	340	165	505
Direct Drainage Echo	58	60	15	–	0	0	28	0	162	0	162
Huff Creek	26	119	6	–	0	70	38	0	260	0	260
Silver Creek	413	216	54	–	4	0	37	0	724	1,262	1,986
South Fork Chalk Creek	37	109	6	–	1	528	89	0	769	0	769
Upper Chalk Creek	5	10	1	–	0	0	30	0	46	0	46
Weber River between Rockport and Echo	51	166	110	–	10	93	297	931	1,658	0	1,658
Total	**683**	**755**	**211**	–	**19**	**691**	**670**	**931**	**3,959**	**1,427**	**5,387**

Table 5.22. Summary of Nonpoint Source Total Nitrogen Loads (kg per summer season [April–September])

Subwatershed	Stormwater	Private Grazing	Irrigation /Fertilizer	Public Grazing	Septic Systems	Channel Erosion	Three Mile Canyon Landfill	Natural Background	Upstream	Total Nonpoint Source	Point Source Load	Total
Rockport Reservoir Watershed												
Beaver Creek	106	315	424	109	450	–	–	526	–	1,930	1,051	2,981
Direct Drainage Rockport	226	746	-	-	779	–	922	275	–	2,948	–	2,948
Lower Weber River	130	497	538	42	544	–	–	979	–	2,731	703	3,434
Smith and Morehouse	4	-	-	1,195	–	–	–	397	–	1,596	–	1,596
Upper Weber River	20	1,584	-	548	509	–	–	792	–	3,453	–	3,453
Weber Canyon	115	1,132	-	1,035	1,214	–	–	665	–	4,161	–	4,161
Total	**601**	**4,275**	**962**	**2,929**	**3,496**	**–**	**922**	**3,634**	**–**	**16,819**	**1,754**	**18,573**
Echo Reservoir Watershed												
Chalk Creek Mainstem	95	2,772	693	-	199	–	–	966	–	4,725	715	5,440
Direct Drainage Echo	99	49	12	-	44	–	–	180	–	384	–	384
Huff Creek	27	540	28	-	2	177	–	245	–	1,019	–	1,019
Silver Creek	522	1,047	262	-	302	–	–	246	–	2,379	11,396	13,775
South Fork Chalk Creek	42	1,024	54	-	6	997	–	572	–	2,695	–	2,695
Upper Chalk Creek	18	1,487	78	-	1	–	–	735	–	2,319	–	2,319
Weber River between Rockport and Echo	130	2,984	1,989	-	539	861	–	958	9,616	17,077	–	17,077
Total	**933**	**9,903**	**3,117**	**-**	**1,093**	**2,035**	**–**	**3,902**	**9,616**	**30,598**	**12,111**	**42,709**

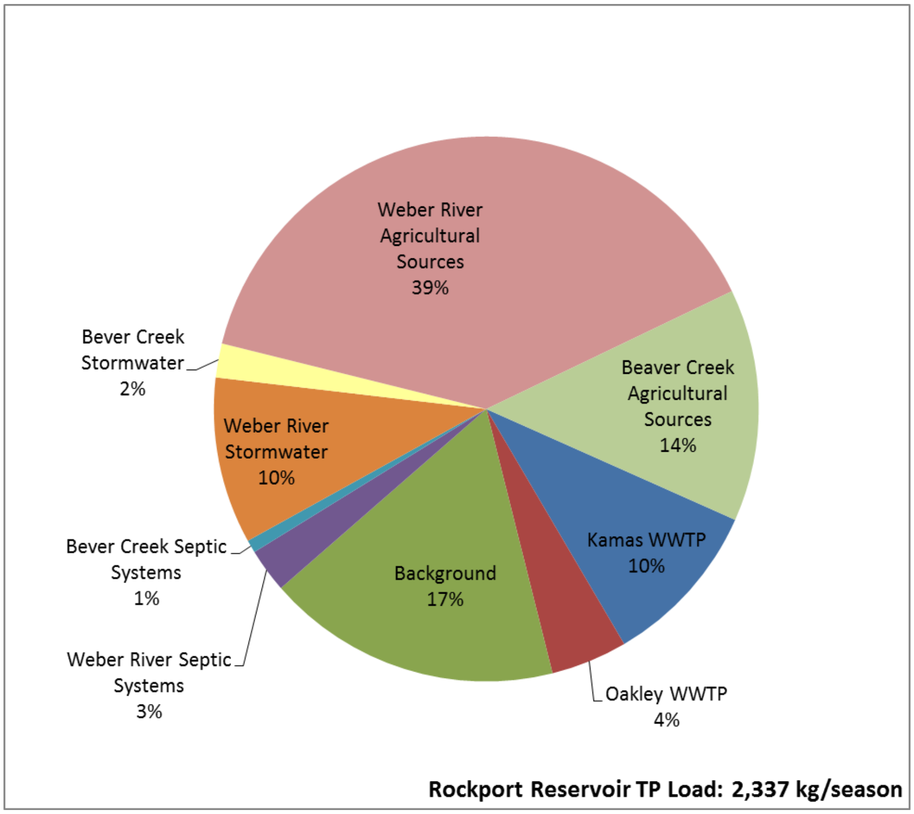

Figure 5.12. Proportion of summer season total phosphorus load associated with significant sources in the Rockport Reservoir watershed.

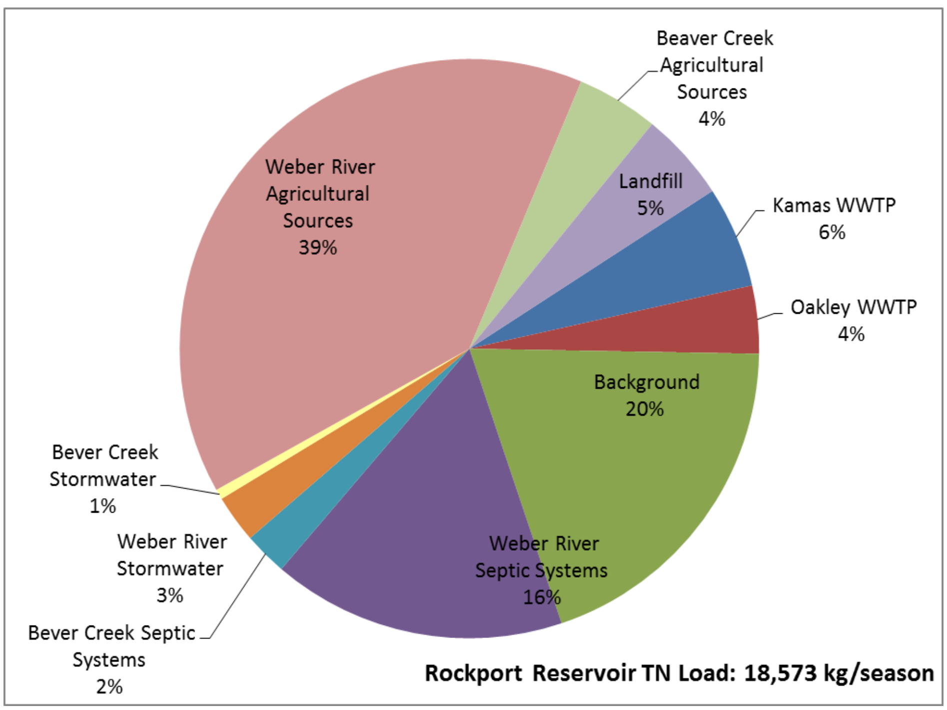

Figure 5.13. Proportion of summer season total nitrogen load associated with significant sources in the Rockport Reservoir watershed.

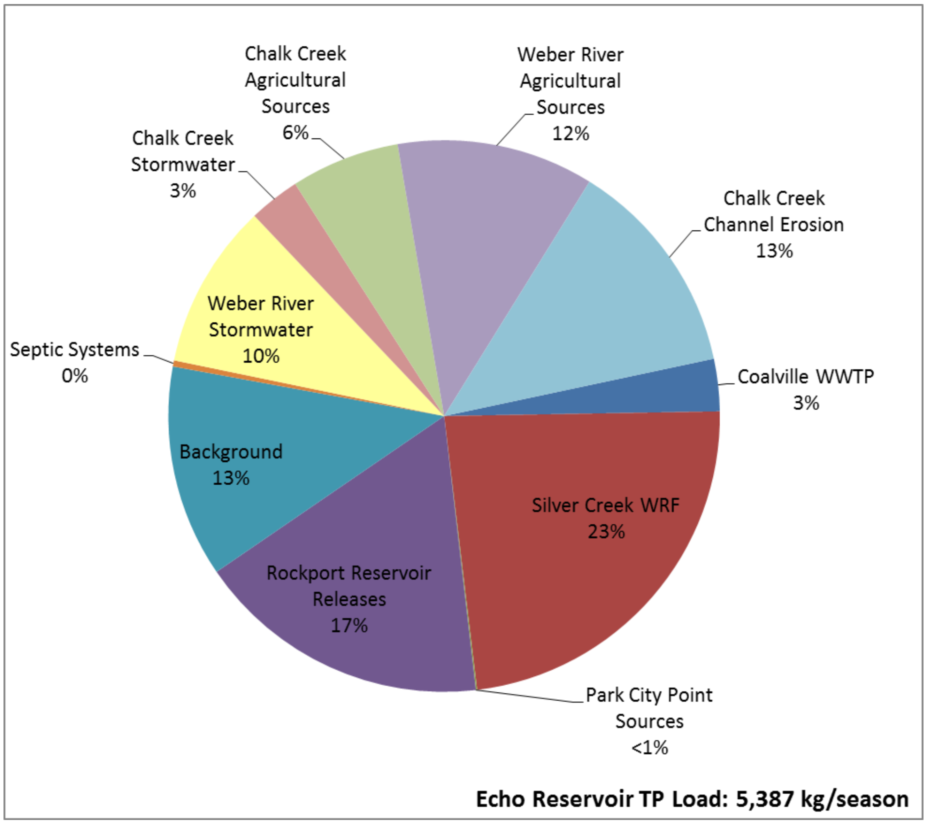

Figure 5.14. Proportion of spring–summer season total phosphorus load associated with significant sources in the Echo Reservoir watershed.

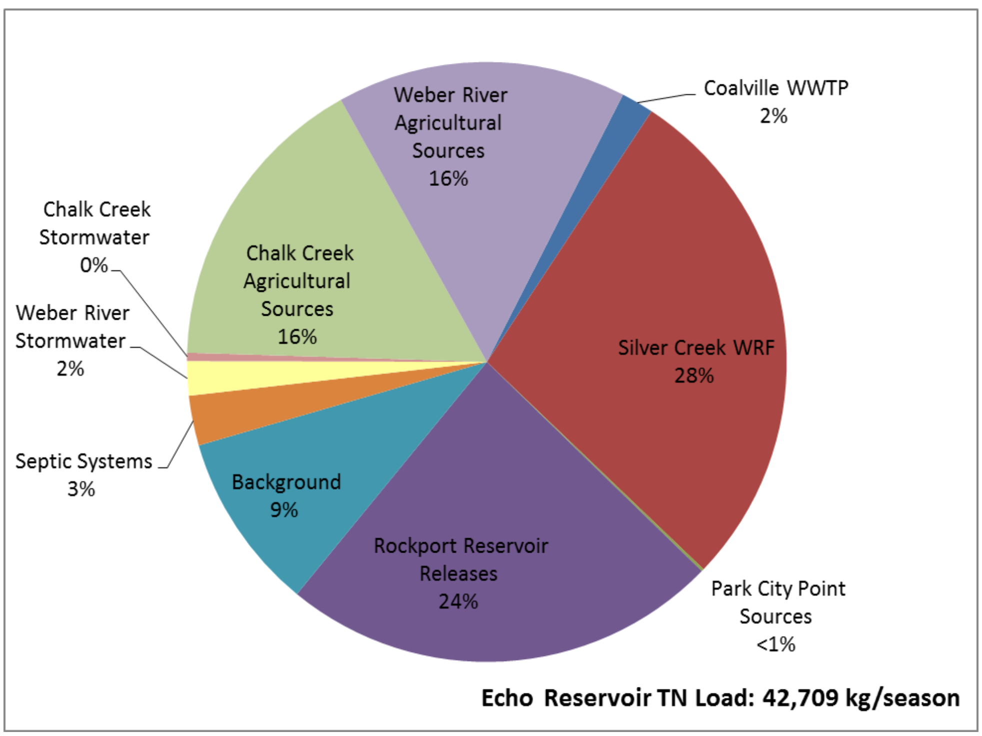

Figure 5.15. Proportion of summer season total nitrogen load associated with significant sources in the Echo Reservoir watershed

5.2. Winter Season

Current loads for the winter season (October 1–March 31) were also calculated (Table 5.23). The current TP load to Rockport Reservoir is 1,022 kg TP/season (5.6 kg TP/day), including a point source load of 467 kg TP/season and a nonpoint source load of 555 kg TP/season. The current TN load to Rockport Reservoir is 9,069 kg TN/season (50 kg TN/day). The point source contribution is 2,758 TN/season, and the nonpoint sources contribute 6,311 kg TN/season (see Table 5.23). The current winter load of TP and TN to Echo Reservoir is 3,901 kg TP/season (21.4 kg/day) and 33,951 kg TN/season (186 kg TN/day). Point sources contribute 1,444 kg TP/day and 9,875 kg TN/season, whereas nonpoint sources contribute 2,457 kg TP/season and 24,076 kg TN/season. Because there is no impairment during the winter, no nutrient reductions are required for the winter season.

Table 5.23. Summary of Current Winter Loads to Receiving Waters and Resulting Loads to the Rockport and Echo Reservoirs

	Total Phosphorus		**Total Nitrogen**	
	Current Load to Receiving Waters (kg/season)	**Current Load to Reservoir (kg/season)**	**Current Load to Receiving Waters (kg/season)**	**Current Load to Reservoir (kg/season)**
Rockport Reservoir				
Point source load	680	467	4,022	2,758
Nonpoint source load	N/A	555	N/A	6,311
Total load	**N/A**	**1,022**	**N/A**	**9,069**
Echo Reservoir				
Point source load	2,078	1,444	14,103	9,875
Nonpoint source load	N/A	2,457	N/A	24,076
Total load	**N/A**	**3,901**	**N/A**	**33,951**

6. TOTAL MAXIMUM DAILY LOAD SUMMARY

6.1. Water Quality Targets and Linkage Analysis

Setting water quality endpoints is critical in the TMDL development process. The goal of the Rockport Reservoir and Echo Reservoir TMDLs is to achieve state water quality criteria to bring designated beneficial uses into full support as quickly as possible. Setting appropriate water quality endpoints is a key prerequisite to the calculation and apportionment of current pollutant loads and the necessary load reductions to support designated beneficial uses. Several methods were employed to derive water quality endpoints for Rockport Reservoir and Echo Reservoir.

The State of Utah has designated Rockport Reservoir and Echo Reservoir as protected for cold-water game fish (Class 3A). This designated beneficial use was identified as impaired on the State of Utah 1996 303(d) list for Echo Reservoir and the 2008 303(d) list for Rockport Reservoir. DO endpoints are based on State Water Quality criteria and, together with warm temperatures, are the direct cause of the impairment of cold-water fisheries (3A) in the reservoir. Low DO in the reservoirs is related to the decomposition of algae and subsequent depletion of DO in the bottom layer (hypolimnion) that does not mix with surface waters during the summer (see Figure 1.1). Oxygen-, nutrient-, and algae-related endpoints were selected based on the direct and indirect influence of algal growth on DO concentrations in both waterbodies. These endpoints were based on a review of relevant scientific literature and results from the BATHTUB models developed for both reservoirs for three reservoir and climatic conditions (dry, wet, and average). Nutrient and algal targets for the reservoirs are based on the correlation between target oxygen depletion rates, associated DO concentrations in the middle layer (metalimnion) of the reservoir, and mean seasonal chlorophyll *a*, TP, and TN concentrations derived from the BATHTUB modeling results.

The primary contributor to low DO in Rockport and Echo Reservoirs is sediment oxygen demand related to annual algal blooms, legacy organic matter, and annual organic matter washed into the system. An increase in nutrients, primarily nitrogen and phosphorus, increases algal growth in the reservoirs, and the subsequent increased amount of decaying organic matter reduces the amount of DO remaining in the water column. Algal blooms, reflected in increases in chlorophyll *a* concentrations, contribute to sediment oxygen demand and oxygen depletion in the reservoir throughout the year. Sediment carrying organic matter can also affect DO concentrations through use of DO in decomposition of the organic matter. Reduction of nutrients is required to reduce the trophic state of the reservoir, reduce algal growth, and improve DO profiles especially during stratification. Decomposition of watershed-derived organic matter represents an unknown component of oxygen depletion in the hypolimnion. Impairment occurs during the spring and summer because the reservoirs stratify during warmer seasons, which creates an upper layer of warm water with sufficient DO and a lower layer of cold water with low DO. It is the low DO concentrations that impair the reservoirs' ability to support a cold-water fishery during the spring and summer, when these reservoirs are likely to be stratified and surface temperatures become too warm for cold-water species.

The BATHTUB model was used to correlate DO endpoints and chlorophyll *a* endpoints with mean seasonal nutrient concentrations. Attainment of the DO endpoints specific to Rockport and Echo Reservoirs correlate with mean seasonal TP and TN concentrations of 0.014 mg/L and 0.26 mg/L, respectively, for Rockport Reservoir and 0.018 mg/L and 0.27 mg/L, respectively, for Echo Reservoir. These nutrient concentrations will result in attainment of the mean seasonal chlorophyll *a* target of 3.5 ug/L for each reservoir, which supports the trophic state target of "mesotrophic" that is necessary to maintain a healthy fishery. Algal concentrations lower than 3.5 would push the system to an oligotrophic condition that would not support the cold water fishery use. These concentrations will therefore serve as the nutrient endpoints for Rockport and Echo Reservoirs.

6.1.1. Dissolved Oxygen Targets

DO is important to the health and viability of the cold-water fishery beneficial use (3A) designated by the State of Utah for Rockport Reservoir and Echo Reservoir. High concentrations of DO (6.0–8.0 mg/L or greater) are necessary for the health and viability of fish and other aquatic life. Low DO concentrations (less than 4.0 mg/L) cause increased stress to fish species, lower resistance to environmental stress and disease, and result in mortality at extreme levels (less than 2.0 mg/L). Low DO in the reservoir is related to the decomposition of algae and other organic matter and subsequent depletion of DO in the hypolimnion.

The goal of the Rockport Reservoir and Echo Reservoir TMDLs is to increase concentrations of oxygen in the reservoir such that the designated beneficial uses are fully supported. Cold-water sport fish species are not known to reproduce in the reservoir; therefore, the early life-stage criteria do not apply. The state DO criteria for all life stages of cold-water fish are 4.0 mg/L as a 1-day minimum, 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average.

All of these criteria are currently attained in the epilimnion of the reservoirs and typically violated in the hypolimnion of the reservoirs at the end of the summer stratification season. The State of Utah applies the 4.0 mg/L standard to a minimum of 50% of the water column in assessing attainability of this standard in deep stratified lakes and reservoirs. In addition, the epilimnion in each reservoir routinely exceeds temperature criteria during the summer season due to solar radiation. To protect the fishery from the intersecting pressures of high temperature in the epilimnion and low DO in the hypolimnion, the following site-specific assessment methodology was implemented for the Rockport and Echo Reservoir TMDLs.

During periods of thermal stratification, the minimum DO criteria of 4.0 mg/L and maximum temperature of 20^{o}C shall be maintained in a 2-m layer across the reservoir to provide adequate refuge for cold-water game fish. This layer is represented by the metalimnion. Further reduction in nutrients would jeopardize the food source for the fishery and thereby would not be supportive of the current use. During periods of complete mixing in the reservoir, all life-stage water quality criteria identified by the State of Utah will be maintained across the reservoir and throughout at least 50% of the water column.

The DO endpoint of 4.0 mg/L for Rockport and Echo Reservoirs is consistent with Utah’s all life stage standard for DO. The acute standard of 4.0 mg/L is the only standard used to assess water column DO profiles in stratified lakes (DWQ 2010). The violation of this standard in more than 50% of the water column resulted in the placement of Rockport Reservoir and Echo Reservoir on the 303(d) list of impaired waters; therefore, it is the focus of the TMDL. The chronic DO standards, including the 7-day and 30-day standards of 5.5 and 6.5 mg/L, respectively, are maintained in the epilimnion of the reservoirs and are not currently violated. This current attainment of water quality standards would not change as a result of improvements in oxygen conditions in the hypolimnion. The DO endpoints for these TMDLs reflect a change in assessment protocol (2 meters of metalimnetic habitat rather than 50% of the water column) rather than a site-specific standard. The TMDL maintains the current DO standards for reservoirs, including 4.0 mg/L at depth in stratified lakes, and the 7-day standard of 5.5 mg/L and the 30-day standard of 6.5 mg/L in the epilimnion (see section 2.4, Tables 2.5 and 2.8 for data demonstrating current attainment of chronic DO standards).

The endpoints for Rockport and Echo Reservoirs were developed in collaboration with the Utah DWR and determined to be protective of the fish species found in the reservoirs based on the current health of the fishery (section 2.4.3) and algal and nutrient targets derived to maintain an adequate food supply (section 6.1.3).

6.1.1.1. METALIMNETIC OXYGEN DEPLETION RATE TARGETS

The goal of attaining a DO concentration of at least 4 mg/L in the metalimnion is correlated with a target metalimnetic oxygen depletion (MOD) rate, a parameter that has been calculated for current reservoir conditions and that can be predicted using the BATHTUB model. The target MOD rate (mg/m^3/day) is calculated by comparing the oxygen concentration below the thermocline at stratification with the target of 4 mg/L to determine how much oxygen can be depleted from the metalimnion and still meet water quality criteria. This value is then divided by the total number of days in the stratification season to determine an acceptable target MOD rate. The target MOD rate is therefore related to the starting oxygen concentration in the reservoir and the number of days in the stratification season. A higher initial oxygen concentration and/or a shorter stratification season would result in a higher target MOD rate (Figure 6.1). The MOD target for Echo Reservoir and Rockport Reservoir is 36.5 mg/m^3/day based on an assumed initial DO concentration of 9.0 mg/L. This target was used to derive TP and nitrogen targets for the reservoir as well as algal-related targets.

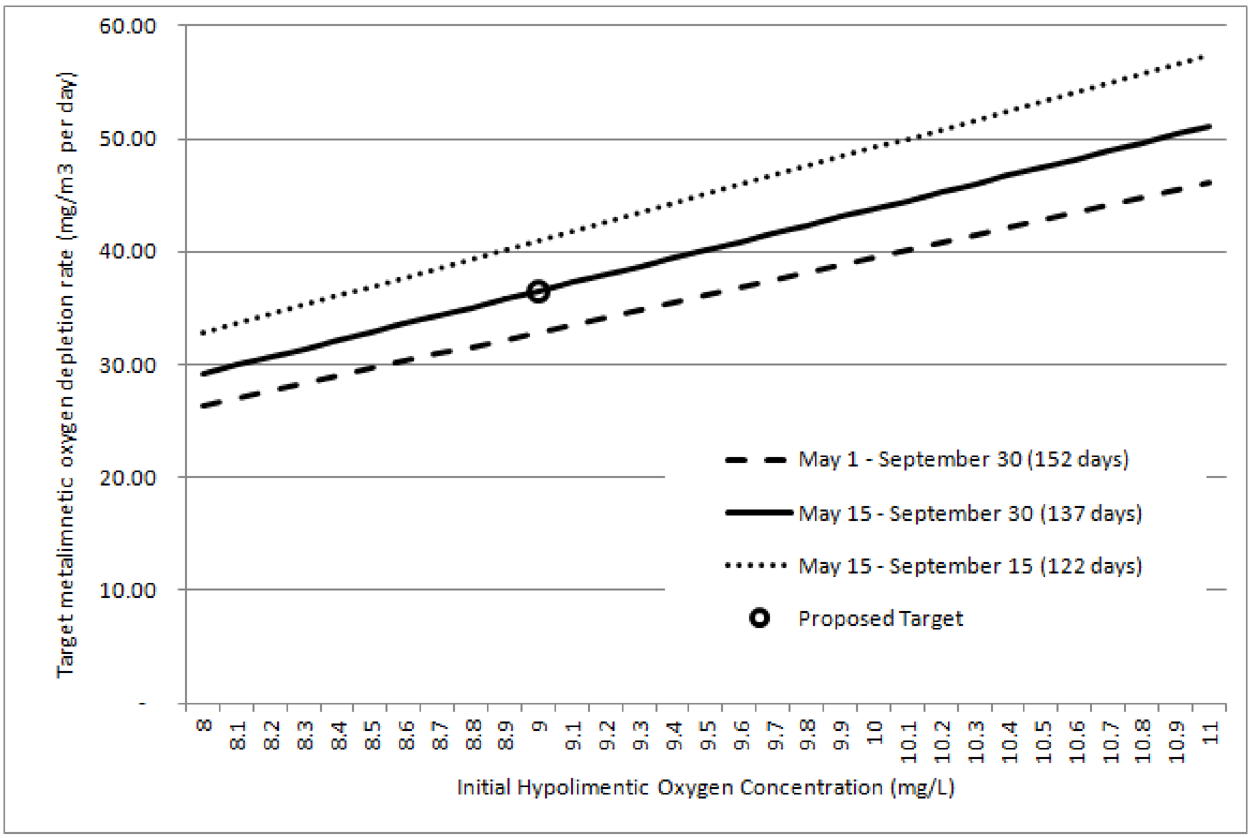

Figure 6.1. Relationship between metalimnetic oxygen depletion rate targets and initial hypolimnetic oxygen concentration for three different assumed stratification seasons and selected target for Rockport Reservoir and Echo Reservoir.

The stratification season for both reservoirs is assumed to be 137 days in length extending from May 15 to September 30. The concentration of DO at the start of stratification, as opposed to during the stratification period, is more difficult to estimate. There are no DO data in early spring, prior to stratification. The earliest spring measurements were taken in Echo Reservoir on May 22, 2007, and on

May 29, 2007 for Rockport Reservoir. The average and maximum surface DO concentrations on those dates were 9.10 mg/L and 9.45 mg/L for Echo Reservoir and 7.9 and 8.0 mg/L for Rockport Reservoir, respectively. Although there are very few DO data for either reservoir at stratification, there are more DO data available for the tributaries into and out of the reservoirs in early spring, and these concentrations also provide some perspective on hypolimnetic oxygen depletion rates, especially the concentrations in the Weber River directly downstream of each dam, recognizing that some aeration of the water will occur upstream of the monitoring site. A summary of these data is provided in Table 6.1 and indicates the initial concentration of oxygen in the hypolimnion could be as high as 10 mg/L in Echo Reservoir. The use of 9.0 mg/L in deriving the MOD rate target is a conservative assumption for the TMDL analysis.

Table 6.1. Summary of Early Spring Dissolved Oxygen Data in Tributaries to and from Rockport Reservoir and Echo Reservoir

	Chalk Creek	Weber River above Rockport Reservoir	Weber River below Rockport Reservoir	Weber River above Echo Reservoir	Weber River below Echo Reservoir
April					
2004	9.6	10.9	9.8	9.8	12.8
2005	9.5	10.0	–	–	–
2006	9.8	10.2	–	–	–
2008	11.0	10.3	–	–	–
2009	1.8	10.0	9.8	11.4	9.4
Average	**8.3**	**10.3**	**9.8**	**10.6**	**11.1**
May					
2001	10.8	11.1	–	–	–
2002	8.8	8.9	–	–	–
2003	8.7	7.9	–	10.3	–
2004	8.9	9.5	10.8	10.6	11.3
2006	15.2	12.0	–	–	–
2007	11.2	10.6	11.0	12.0	9.2
2009	9.8	9.8	9.1	11.5	9.4
Average	**10.3**	**10.0**	**10.4**	**11.0**	**10.3**

6.1.2. Nutrient Targets

Average seasonal water quality in the reservoirs, based on a 35% nutrient reduction scenario for each condition, are presented in Tables 6.2 and 6.3. The target TP and TN concentrations in Rockport Reservoir are 0.014 mg/L and 0.26 mg/L under average conditions, respectively. The target TP and TN concentrations in Echo Reservoir are 0.018 mg/L and 0.27 mg/L, respectively. The average condition concentrations are used in the TMDL analysis to determine the quantity of nutrient reductions.

Table 6.2. Predicted Rockport Reservoir Nutrient Concentrations under Current Load and Proposed Nutrient Load Reductions of 35%

	Dry	Average	Wet
Current			
Total phosphorus (mg/L)	0.043	0.019	0.034
Total nitrogen (mg/L)	0.409	0.394	0.381
Secchi depth (m)	3.6	3.9	3.5
Organic nitrogen (mg/L)	0.347	0.325	0.312
Orthophosphate (mg/L)	0.012	0.011	0.0094
Target Water Quality			
Total phosphorus (mg/L)	0.027	0.014	0.023
Total nitrogen (mg/L)	0.268	0.257	0.260
Secchi depth (m)	6.2	6.1	5.7
Organic nitrogen (mg/L)	0.236	0.239	0.251
Orthophosphate (mg/L)	0.004	0.004	0.005

Table 6.3. Predicted Echo Reservoir Nutrient Concentrations under Current Load and Proposed Nutrient Load Reductions of 35%

	Dry	Average	Wet
Current			
Total phosphorus (mg/L)	0.019	0.025	0.035
Total nitrogen (mg/L)	0.348	0.408	0.405
Secchi depth (m)	4.5	3.7	3.0
Organic nitrogen (mg/L)	0.293	0.337	0.393
Orthophosphate (mg/L)	0.008	0.011	0.015
Target Water Quality			
Total phosphorus (mg/L)	0.014	0.018	0.025
Total nitrogen (mg/L)	0.246	0.266	0.274
Secchi depth (m)	6.7	5.9	5.3
Organic nitrogen (mg/L)	0.227	0.244	0.264
Orthophosphate (mg/L)	0.003	0.004	0.006

6.1.3. Algal Targets

Algae-related endpoints were selected to 1) reduce the direct and indirect effects of plant overgrowth on DO concentrations, 2) address the periodic overgrowth of algae that violates the narrative standard for waters established by the State of Utah, 3) prevent conversion to dominance of blue-green algae, and 4) maintain a food supply for the fishery. Overgrowth of algae violates the narrative standard for waters established by the State of Utah, which requires waters to be maintained such that they do not become offensive by "unnatural deposits, floating debris, oil, scum, or other nuisances such as color, odor or taste…or result in concentrations or combinations of substances which produce undesirable human health effects…" (Utah State Code R317). In addition to algal overgrowth, prevention of blue-green algal dominance is important for protection of beneficial uses in Rockport and Echo Reservoirs. Blue-green algae blooms can cause the formation of surface scums and the potential release of toxins harmful to humans, livestock, and pets. There are no known reports of toxic cyanobacteria blooms in Rockport Reservoir or Echo Reservoir, a condition that must be maintained. Each reservoir supports a fishery that relies on algae as a part of the food web and as habitat; however, low DO in the deeper portions of the reservoirs related to decomposition and plant respiration are stressful to fish, particularly when surface water temperatures increase during the summer. High surface water temperatures force fish to deeper parts of the reservoir to avoid the warmer water, but deeper waters during the summer periods are more likely to be low in DO or anoxic and therefore of limited use as refugia for fish.

Two algal-related endpoints were identified for Rockport and Echo Reservoirs:

1. Mean seasonal chlorophyll *a* values of 3.5 µg/L
2. Dominance by algal species other than blue-green algae

The mean seasonal chlorophyll *a* endpoint of 3.5 µg/L was derived from the BATHTUB model results, which are in the range of median values for reservoirs in western forested mountains (Table 6.4). A summary of chlorophyll *a* data from 1990 to 1998 in Ecoregion 2 (Western Forested Mountains) is provided below (Table 6.4). The statistical summaries are based on data from 441 lakes and reservoirs and include 3,931 records for chlorophyll *a*. The nutrient criteria technical guidance manual (EPA 2000) suggests that the lower 25th percentile of ecoregional data is representative of the reference condition, when not all lakes and reservoirs are considered to be in the reference condition. However, the target value of 3.5 µg/L is more protective of Echo Reservoir during average conditions (Table 6.5).

Table 6.4. Summary Statistics for Chlorophyll *a* (µg/L) Data from Lakes and Reservoirs in the Western Forested Mountains Ecoregion

Season	25th Percentile	Median	75th Percentile
Fall	1.8	3.1	6.7
Spring	2.1	4.4	8.6
Summer	1.4	2.9	5.9
Winter	3.5	5.8	6.2

Table 6.5. Predicted Rockport Reservoir Chlorophyll *a* (µg/L) Concentrations under Proposed Nutrient Load Reductions

	Dry	Average	Wet
Current (predicted)			
Rockport Reservoir	8.1	7.1	8.1
Echo Reservoir	5.7	7.6	10.1
Target Water Quality			
Rockport Reservoir	3.2	2.7	3.9

Echo Reservoir	2.8	3.6	4.4

6.1.4. Trophic State Target

Although improvements to the DO conditions in Rockport Reservoir and Echo Reservoir are critical to maintaining a health cold water fishery, other aspects of the reservoir ecosystem must also be considered. Reduction of nutrients also affects algal concentrations in the reservoir that are the primary producers for the food webs in the reservoir. Without sufficient primary production, the fish would not have enough food to grow to a healthy weight. The DWR has found that the balance between improving oxygen concentrations and food availability occurs through maintaining the reservoirs in a mesotrophic state (personal communication, Erica Gaddis, SWCA, and Chris Penne, DWR, January 7, 2014). If the reservoirs were to become oligotrophic, the DWR would need to stock larger fish to compensate for the lack of food. This would present an economic hardship for the state and may make it difficult for the fishery to be maintained at current stocking rates. TMDL targets for chlorophyll *a* and phosphorus were derived to fall within the mesotrophic range so as not to degrade the health of the fishery (Table 6.6) and to fully support current stocking and size rates. Mesotrophic conditions are considered to be a chlorophyll *a* concentration between 2 and 7 µg/L (EPA 2010) and a total phosphorus concentration between 10 and 20 µg/L (Vollenweider 1976).

Table 6.6. Trophic State TMDL Targets for Echo and Rockport Reservoirs and Current Statistics (2002 – 2011)

	Current Average	Current Range	TMDL Average	TMDL Range
Echo Reservoir				
TP	23	19–36	18	14–25
Chlorophyll *a*	5.6	4.9–6.9	3.6	2.8–4.4
Trophic state	Eutrophic		Mesotrophic	
Rockport Reservoir				
TP	21	21–43	14	14–23
Chlorophyll *a*	5.8	5.8–8.1	3.3	3.2–4.9
Trophic state	Eutrophic		Mesotrophic	

Note: Oligotrophic is defined as < 2 µg/L and < 10 µg/L TP; mesotrophic is defined as 2–7 µg/L chlorophyll *a* and 10–20 µg/L TP; eutrophic is defined as > 7 µg/L chlorophyll *a* and > 20 ug/L TP (EPA 2010; Vollenweider 1976).

6.2. Future Growth

The combined Rockport Reservoir and Echo Reservoir watershed is approximately 464,000 acres with over 99% of the land in Summit County, Utah. The population of Summit County was estimated at 36,324 in 2010. Summit County is made up of seven primary municipalities; their 2000 and 2010 populations are shown in Table 1.1. As of May 2012, the county had 13,103 non-primary residential structures versus 12,613 primary residential structures. These include cabins, condominiums, mobile homes, and standard homes; these do not include commercial, vacant land, or exempt properties.

The county as a whole is projected to grow by 56% by 2030, compared to a 42% projected growth for the entire State of Utah (Table 6.7). Much of this growth is projected for small towns and rural areas in the county, outside of Park City (State of Utah 2012). A large portion of the population growth in the watershed is expected to occur in the Echo Reservoir watershed. The population in the Synderville Basin is expected to more than double by 2030. Population estimate reports show Park City growing from 7,497 in 2005 to 16,312 in 2030, a 54% increase. Summit County lands in the Snyderville Basin are expected to accommodate 31,887 people by 2030; a 51% increase from 15,734 people in 2005 (see section 1.3.2 for population projections). The majority of new residential development is likely to occur on the basin floor and on hillsides with less than a 25% slope. Commercial development will be concentrated along Interstate 80 and Highways 224, 40, and 248. A large portion of the Snyderville Basin is zoned for residential development. The Rural Residential zone (Figure 6.2) allows existing residential uses to continue and allows for the construction of new single family dwelling units. The base density is 1 unit/per 20 acres on developable lands and 1 unit/40 acres on sensitive lands. The Hillside Stewardship zone accommodates residential development in areas that contain slopes ranging from 15% to 25% with a base density of 1 unit/30 acres on developable lands and 1 unit/40 acres on sensitive lands. Lands in this zone are more susceptible to erosion, and development in these areas may negatively affect water quality. Residential development in the Mountain Remote zone is minimal (1 unit/120 acres on developable and sensitive lands) because the location and terrain do not allow for easy access to local service providers. Development in the Mountain Remote Zone is also minimized in order to protect the natural environment and water quality, to lessen fire danger, to minimize viewshed disturbances, and to promote the open space values of the Snyderville Basin (Summit County 2008). Commercial development and light industry are concentrated along I-80 and Highways 224, 40, and 248. Densities for the Community Commercial zone and Service Commercial/Light Industrial zone are not specified. In the Neighborhood Commercial zone, no single structure will contain more than 5,000 square feet.

Table 6.7. Population of Rockport Reservoir and Echo Reservoir Watersheds

Area	Population 2000[1]	Population 2010[1]	Population 2030[2]	Percentage Growth 2010–2030
State of Utah	2,223,169	2,763,885	3,913,605	42%
Summit County	29,736	36,324	56,890	56%
Echo Reservoir Watershed				
Park City	7,371	7,547	11,444	52%
Coalville City	1,382	1,363	1,859	36%
Subtotal	**8,753**	**8,910**	**13,303**	**49%**
Rockport Reservoir Watershed				
Kamas City	1,274	1,811	2,864	58%
Oakley City	948	1,470	3,297	124%
Subtotal Population with Wastewater Treatment	**2,222**	**3,281**	**5,981**	**82%**

[1] Data from Economic Report to the Governor (State of Utah 2011).

[2] Data from Governor's Office of Management & Budget, 2012 Baseline Projections(State of Utah 2012)

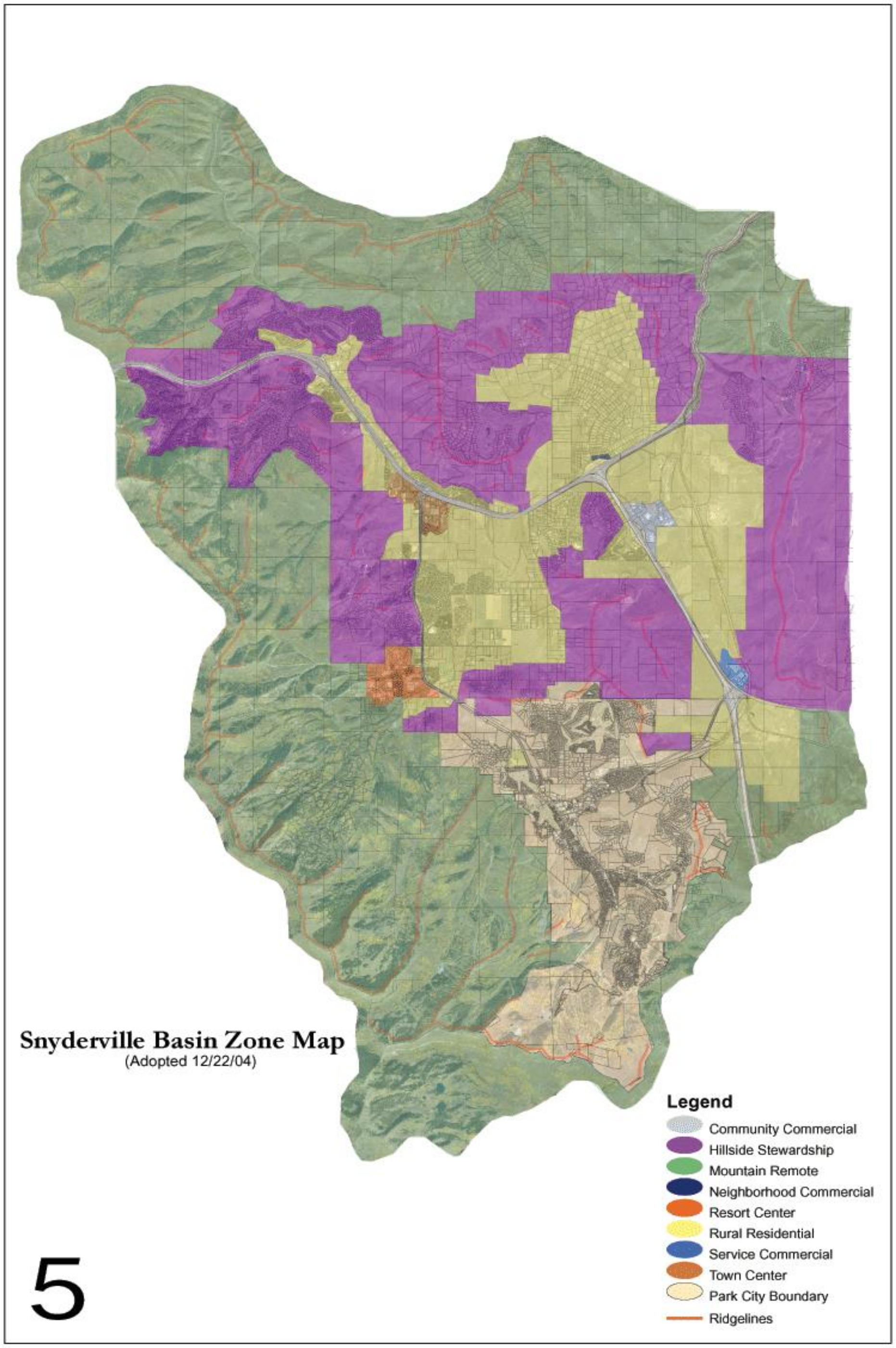

Figure 6.2. Snyderville Basin zoning map (Summit County 2008).

Assuming no new WWTPs are planned, new residential and commercial development in the watersheds will require additional connections to an existing WWTP. As evidenced by the land use map (see Figure 5.5), the majority of undeveloped land is shrub/scrub, agricultural land, open space, or forest, with significant low-density urban land uses already present in the Silver Creek subwatershed and the Weber Canyon subwatershed.

The Coalville WWTP is currently in the process of upgrading. Their current summer flow is 0.21 MGD, but they are projecting a future flow of 0.291 MGD. The Oakley WWTP flow of 0.15 MGD is currently well below their capacity flow of 0.25 MGD and less than half the projected future flow. The Snyderville Basin Water Reclamation District, which operates the Silver Creek WRF, has already determined that anticipated growth in their service district will require expansion of the Silver Creek WRF. Current average daily flow from the Silver Creek WRF is 1.23 MGD with capacity flows of approximately 2.0 MGD. Accommodation of the expected population growth in the Silver Creek subwatershed basin will require expansion of the treatment system with an average discharge of 4.0 MGD, twice the current capacity flow (Table 6.8).

The Blue Sky Resort WWTP is included as a future source because it is currently permitted to discharge, but the facility has not been constructed and is therefore not currently discharging. This future source is permitted with an offset for phosphorus related to removing the grazing operations on the Blue Sky Resort property. Similarly, the Francis WWTP is currently negotiating a discharge permit with DWQ and growth expectations in that area will be reflected in that permit. The DWR fish hatchery in Kamas and the Park City tunnels are not affected by growth in the watershed. The loads from these sources are expected to remain at current levels over the next 10 years (Table 6.8).

Table 6.8. Projected Increase in Wastewater Discharges Resulting From Projected Population Growth

Point Source	Current Summer Flow (MGD)	Capacity Flow (MGD)	Future Flow 2030 (MGD)	Capacity Source	Future Design Flow Source
Rockport Reservoir Watershed					
Kamas WWTP	0.14	0.40	–	Permit	$\%growth \times current\ flow$
Oakley WWTP	0.15	0.25	0.330	Permit	$\%growth \times current\ flow$[2]
DWR Kamas Fish Hatchery	–	3.41	3.410	Current	No growth
Francis WWTP	–	0.14	0.36	DWQ staff	DWQ staff
Echo Reservoir Watershed					
Coalville WWTP	0.21	0.42	0.291	Permit[1]	Design
Silver Creek WRF	1.23	2.00	4.000	Self-reported	Design
Park City tunnels total	2.02	2.02	2.020	Current	No growth
Blue Sky	–	0.03	0.040	Permit	Design

[1] No capacity listed for peak flow; design flow assumed 0.60 in statement of basis analysis.

[2] The future design flow is calculated as the current flow multiplied by expected growth.

Future growth in the watershed also affects the nonpoint source loads. Conversion from agricultural to low-density urban areas has two main effects: 1) increases in impervious surface cover resulting in increased stormwater runoff and 2) reduction in nutrient loads from agricultural activities. These effects are not necessarily equivalent, meaning that nutrient loads may or may not be reduced under a scenario of urbanization. Moreover, increased urbanization generally changes the hydrology of the area to a more flashy system that will generate more erosion from storm events.

6.3. Total Maximum Daily Load Analysis

6.3.1. Current Load Summary and Total Maximum Daily Loads

6.3.1.1. SUMMER SEASON TMDL

Current loads and TMDL loads for the summer season, expressed as daily and seasonal (April 1–September 30) averages, are summarized for Rockport and Echo Reservoirs in Table 6.9. Although daily loads are presented, seasonal loads are considered to be the most appropriate averaging period for this TMDL. The seasonal loads, rather than daily total maximum loads, are the most appropriate for establishing discharge UPDES permits associated with this TMDL.

The current TP load to Rockport Reservoir is 2,337 kg TP/season (12.8 kg TP/day), including a point source load of 337 kg TP/season (1.9 kg TP/day) and a nonpoint source load of 2,000 kg TP/season (10.9 kg TP/day). The current TN load to Rockport Reservoir is 18,573 kg TN/season (102 kg TN/day). The point source contribution is 1,754 kg TN/season (9.6 kg TN/day), and the nonpoint sources contribute 16,819 kg TN/season (92 kg TN/day).

Results from the BATHTUB model (see Appendix A) indicate that attainment of water quality endpoints identified for the waterbody requires a reduction of the TP load to Rockport Reservoir of 818 kg TP/season, which represents an overall reduction of 35% and a total seasonal load of 1,519 kg TP/season. The target seasonal load corresponds to an average daily load of 8.3 kg TP/day. However, daily average could vary with hydrology over the season and is expected to be attained only on average over the course of the season. The target reduction for TN is 6,501 kg TN/season, also a 35% reduction. This reduction corresponds to a total seasonal load of 12,072 kg TN/season, or an average daily load of 66.3 kg TN/day during the season. As with TP, the daily value will vary and is expected to be attained as an average over the season (Table 6.10).

The current load of TP and TN to Echo Reservoir is 5,387 kg TP/season (29.6 kg/day) and 42,709 kg TN/season (235 kg TN/day). Point sources contribute 1,427 kg TP/day (8 kg TP/day) and 12,111 kg TN/season (66.5 kg TN/day), whereas nonpoint sources contribute 3,959 kg TP/season (21.7 kg TP/day) and 30,598 kg TN/season (168 kg TN/day). BATHTUB results indicate that attainment of water quality endpoints identified for Echo Reservoir requires a 35% reduction for both TP and TN. This reduction is 1,885 kg TP/season (10.4 kg TP/day), resulting in a load of 3,502 kg TP/season (19.2 kg TP/day). Total nitrogen must be reduced by 14,948 kg TN/season (82 kg TP/day) with a resulting load of 27,761 kg TN/season (141 kg TN/day). Again, the daily value will vary and is expected to be attained as an average over the season (Table 6.10).

Table 6.9. Summary of Current Summer (April–September) Loads to Receiving Waters and Resulting Loads to the Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Current Load to Receiving Waters (kg/season)	**Current Load to Reservoir (kg/season)**	**Current Load to Receiving Waters (kg/season)**	**Current Load to Reservoir (kg/season)**
Rockport Reservoir				
Point source load	500	337	2,603	1,754
Nonpoint source load	N/A	2,000	N/A	16,819

Table 6.9. Summary of Current Summer (April–September) Loads to Receiving Waters and Resulting Loads to the Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Current Load to Receiving Waters (kg/season)	**Current Load to Reservoir (kg/season)**	**Current Load to Receiving Waters (kg/season)**	**Current Load to Reservoir (kg/season)**
Total load	**N/A**	**2,337**	**N/A**	**18,573**
Echo Reservoir				
Point source load	2,057	1,427	17,751	12,111
Nonpoint source load	N/A	3,959	N/A	30,598
Total load	**N/A**	**5,387**	**N/A**	**42,709**

Table 6.10. Summary of Maximum Total Phosphorus and Total Nitrogen Summer (April–September) Seasonal and Daily Loads for Attainment of Water Quality Standards in Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Average Season (kg/season)	**Average Daily (kg/day)**	**Average Season (kg/season)**	**Average Daily (kg/day)**
Rockport Reservoir				
Nonpoint source load allocation	952	5.2	6,853	37.7
WLA for point sources at current capacity	495	2.8	4,504	24.7
WLA for point sources future growth	72	0.4	716	3.9
MOS	0	0	0	–
Total load to reservoir	**1,519**	**8.3**	**12,072**	**66.3**
Echo Reservoir				
Nonpoint source load allocation	1,779	9.8	10,605	58.3
WLA for point sources at current capacity	1,237	6.8	12,238	67.2
WLA for point sources future growth	485	2.7	4,918	27.0
MOS	0	0	0	0
Total load to reservoir	**3,502**	**19.2**	**27,761**	**152.5**

6.3.1.2. ANNUAL TMDL

Annual load allocations represent the TMDL from the summer critical season and the current winter loads to the reservoir. Although winter loads are not currently contributing to the impairment, to prevent backsliding and to preserve the no net internal load condition during the summer critical season, the annual TMDL assumes no net increase in current winter loads and allocates loads to point and nonpoint sources on an annual basis. This TMDL is in addition to the summer critical season TMDL that forms the primary load targets and reduction for the reservoirs. An annual TMDL, rather than a winter season

TMDL, was selected to provide more flexibility to point sources in the watershed to transfer summer loads to the winter. However, due to the summer season TMDL, no winter loads could be transferred to the summer. As with the summer season TMDL, loads have been calculated for both receiving waters and delivery to the reservoir (Table 6.11). Wasteload allocations for the annual TMDL are based on the summer season TMDL wasteload allocations and additional load calculated using current capacity flow (Table 6.12) and concentrations of 10 mg/L and 1 mg/L for total nitrogen and total phosphorus, respectively. Future growth wasteload allocations are similarly calculated using projected future flows (see Table 6.12) and nutrient concentrations in the effluent of 10 mg/L and 1 mg/L for total nitrogen and total phosphorus, respectively. Annual reductions account for a summer reduction of 35% and a winter reduction of 0% resulting in an annual nutrient reduction of 24% to Rockport Reservoir and 20% to Echo Reservoir.

Table 6.11. Summary of Current Annual Loads to Receiving Waters and Resulting Loads to the Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Current Load to Receiving Waters (kg/year)	**Current Load to Reservoir (kg/year)**	**Current Load to Receiving Waters (kg/year)**	**Current Load to Reservoir (kg/year)**
Rockport Reservoir				
Point source load	1,180	804	6,625	4,512
Nonpoint source load	N/A	2,555	N/A	23,130
Total load	**N/A**	**3,359**	**N/A**	**27,642**
Echo Reservoir				
Point source load	4,135	2,871	31,854	21,986
Nonpoint source load	N/A	6,417	N/A	54,674
Total load	**N/A**	**9,288**	**N/A**	**76,660**

Table 6.12. Summary of Maximum Total Phosphorus and Total Nitrogen Annual and Daily Loads for Attainment of Water Quality Standards in Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Average Year (kg/year)	**Average Daily (kg/day)**	**Average Year (kg/year)**	**Average Daily (kg/year)**
Rockport Reservoir				
Nonpoint source load allocation	1,095	3	7,608	21
WLA for point sources at current capacity	990	3	9,008	25
WLA for point sources future growth	456	1	4,525	12
MOS	0		0	
Total load to reservoir	**2,541**	**7**	**21,141**	**58**
Echo Reservoir				
Nonpoint source load allocation	3,474	10	22,517	62
WLA for point sources at current capacity	2,473	7	24,440	67

Table 6.12. Summary of Maximum Total Phosphorus and Total Nitrogen Annual and Daily Loads for Attainment of Water Quality Standards in Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Average Year (kg/year)	**Average Daily (kg/day)**	**Average Year (kg/year)**	**Average Daily (kg/year)**
WLA for point sources future growth	1,455	4	14,755	40
MOS	0		0	
Total load to reservoir	**7,403**	**20**	**61,712**	**169**

6.3.2. Margin of Safety

The CWA requires that the total load capacity "budget" calculated in TMDLs must also include an MOS. The MOS accounts for uncertainty in the loading calculation. The MOS can differ for each waterbody due to variation in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs via the use of conservative assumptions in the load calculation, or it can be specified explicitly as a proportion of the total load. The Rockport Reservoir and Echo Reservoir TMDLs rely on conservative assumptions to meet the MOS requirement. These include the following:

1. **Organic matter loading to reservoirs was not accounted for in oxygen depletion rate predictions.** The BATHTUB models were calibrated to oxygen depletion rates assumed to be driven by algal growth and nutrients in the reservoirs. However, organic matter loading to the hypolimnia from the watersheds could also contribute to oxygen depletion. Thermal stratification may confine these effects to the hypolimnion during the spring-summer season. The water temperature of the Weber River is lower than the surface temperature of the reservoirs in the summer. Accordingly, much of the water delivered to the reservoirs in the summer may bypass the surface and sink to the hypolimnion directly. While the effect of this phenomenon on nutrient loads to the epilimnion has been accounted for through calibration of nutrient sedimentation rates in the reservoir, the BATHTUB model does not account for additional oxygen depletion associated with organic matter. Further, there are very few data related to organic matter loading from the Weber River to the reservoirs that could be used in any analysis of this potential driver. Thus, contribution to oxygen depletion from organic matter is not accounted for in the current analysis. This is a protective assumption, in that all of the improvement in oxygen depletion will be achieved through nutrient reductions. Any BMPs implemented to reduce nutrients in the watershed would likely also reduce organic matter loading as both nutrient and organic matter transport are associated with soil erosion and sediment transport from the watershed.

2. **Selection of conservative MOD rate target.** The concentration of oxygen in the hypolimnion at stratification is a critical assumption in calculating an acceptable oxygen depletion rate for each reservoir. No hypolimnetic oxygen data are available for either reservoir in April or early May. DO data from reservoir surfaces in late May and in the Weber River below each reservoir in April and May were used to develop an assumed initial DO concentration for the reservoirs. In addition, calculated MOD rates based on profile data were used to backcast initial DO rates. Although the initial DO concentrations could be as high as 10.0 mg/L, 9.0 mg/L was assumed for the analysis as a conservative assumption.

3. **Selection of very low nutrient targets indicative of reference lakes in the Ecoregion.** The target water quality for nutrients, based on the BATHTUB modeling, results in very low nutrient concentrations in the surface of both reservoirs. It should be further noted that the average seasonal phosphorus concentrations in some years in which DO impairments have been observed are already below the threshold value (0.025 mg/L) identified by the State of Utah to indicate a nutrient concern. These targets are sufficiently protective of the uses designated to Rockport Reservoir and Echo Reservoir. Further reductions could threaten the fishery by reducing the available algae for food.

4. **Conservative assumptions in modeling.** Sources of uncertainty and variability associated with all models including SWAT and BATHTUB relate to data representativeness or the uncertainty and variability for data used for calibration, uncertainty and variability in the values used to characterize parameters, and uncertainty in the understanding of the processes occurring and the equations and parameters used in the model to simulate processes. Conservative assumptions were made in each case to ensure the final TMDL is protective of water quality, and these assumptions are included in the model development discussion (Appendix A).

6.3.3. Load Allocation and Rationale

The EPA provides guidance in allocating loads to point and nonpoint sources in TMDLs (EPA 1999). The *Protocol for Developing Nutrient TMDLs* states that dividing the assimilative capacity of a given waterbody among sources should consider the following issues: economics, political considerations, feasibility, equitability, types of sources and management options, public involvement, implementation, limits of technology, and variability in loads and effectiveness of BMPs (EPA 1999). All of these have been considered in determining load allocations for Rockport Reservoir and Echo Reservoir.

To achieve equity among point sources in the watershed, waste load allocations (WLAs) are based on assigning the same TP (1.0 mg/L) and TN concentrations (10.0 mg/L) to the current capacity flows for each point source in the watershed. These values are consistent with the technology-based nutrient criteria currently proposed for the State of Utah (1.0 mg/L TP and 10.0 mg/L of total inorganic nitrogen). WLAs are generally greater than current loads because current loads are based on current flows and WLAs are based on capacity flows. In almost every case, the WLAs will require nutrient reductions from current concentrations in point sources. The exception to this is Coalville City, which has been achieving lower nutrient concentrations in their effluent than the treatment plant is designed to achieve. Coalville City is currently in the process of constructing a new WWTP, and it is unlikely that the lower nutrient concentrations can be achieved with the new facility designed to meet nutrient concentrations of 1.0 mg/L TP and 10 mg/L total inorganic nitrogen. Due to the large projected growth in the watershed, two treatment plants will need to be expanded above current capacity flows in the future (Silver Creek WRF in the Echo Reservoir watershed and Oakley WWTP in the Rockport Reservoir watershed). WLAs associated with the expanded flow are based on lower nutrient concentrations of 0.5 mg/L TP and 5.0 mg/L TN. Although the permits associated with the TMDL will not need to require concentration-based limits, the permitted loads reflect average concentrations described above. In addition, a WLA is included for one permitted point sources that is not currently operating. The Blue Sky Ranch is preparing to construct a small permitted WWTP that will discharge to the lower reaches of Silver Creek.

Summer season WLAs for currently permitted point sources in the Rockport Reservoir watershed are 495 kg TP/season and 4,504 kg TN/season (Table 6.13). Additional WLAs for future growth were assigned to the Oakley WWTP for 19 kg TP/season and 190 kg TN/season and to the Francis WWTP for 53 kg TP/season and 526 kg TN/season. The nonpoint source load allocation for the watershed is 952 kg TP/season and 6,853 kg TN/season, requiring a 72% and 68% reduction, respectively, from current nonpoint source loads. Summer season WLAs for currently permitted point sources in the Echo Reservoir watershed are 1,237 kg TP/season and 12,238 kg TN/season (Table 6.14). An additional WLA for future growth was assigned to the Silver Creek WRF for 485 kg TP/season and 4,918 kg TN/season. The nonpoint source load allocation for the watershed is 1,779 kg TP/season and 10,605 kg TN/season, requiring a 70% and 87% reduction, respectively, from current nonpoint source loads. Load allocations will be further differentiated for both reservoirs in the implementation plan.

Although summer is the critical season for DO exceedances in the reservoirs, winter WLAs were developed to be protective of the reservoir all year. Because internal nutrient loading during the summer, associated with winter loads of nutrients, is not a major concern in the reservoirs, the WLAs are slightly higher than the summer WLAs. The winter WLAs are based on the capacity flow for each point source and target effluent concentrations of 1.0 mg/L TP and 10.0 mg/L TN. This is identical to the WLAs for the summer season. The WLAs for future growth are based on the added flow projected to be associated with growth and target effluent concentrations of 1.0 mg/L TP and 10.0 mg/L TN, a higher effluent target than the future growth targets identified for the summer season. Tables 6.15 and 6.16 summarize the WLAs for the summer season and annual TMDLs. winter and summer seasons.

Table 6.13. Summary of Maximum Total Phosphorus and Total Nitrogen Summer (April–September) Seasonal and Daily Loads for Attainment of Water Quality Standards in Rockport Reservoir

	Total Phosphorus					Total Nitrogen				
	Current Load to Reservoir (kg/season)	**Allocated Load to Reservoir[1] (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**	**Delivery Ratio**	**Current Load to Reservoir (kg/season)**	**Allocated Load to Reservoir (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**	**Delivery Ratio**
Waste Load Allocations, Current										
Kamas WWTP (UPDES UT0020966)	231	183	1.0	-21%	66%	1,051	1,835	10.1	+75%	66%
Oakley WWTP (UPDES UT0020061)	106	120	0.7	+13%	70%	703	1,198	6.6	+70%	69%
DWR Kamas Fish Hatchery (general permit)	N/A	124	0.7	N/A	70%	N/A	802	4.4	N/A	69%
Francis WWTP (UPDES UTOP00202)	N/A	68	0.4	N/A	70%	N/A	669	3.7	N/A	69%
Subtotal	*337*	*495*	*2.8*	*+46.9%*	–	*1,754*	*4,504*	*24.7*	*+157%*	–
Waste Load Allocations, Reserved for Future Growth										
Oakley WWTP (UPDES UT0020061)	N/A	19	0.1	N/A	70%	N/A	190	1.0	N/A	69%
Francis WWTP (UPDES UTOP00202)	N/A	53	0.3	N/A	70%	N/A	526	2.9	N/A	69%
Subtotal	*N/A*	*72*	*0.4*	*N/A*	–	*N/A*	*716*	*3.9*	*N/A*	–
MOS	–	0	–	–	–	–	0	–	–	–
Nonpoint source load allocation	2,000	952	5.2	-52%	–	16,819	6,853	37.7	-59%	–
Total load to reservoir	**2,337**	**1,519**	**8.3**	**-35%**	–	**18,573**	**12,072**	**66.3**	**-35%**	–

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

Table 6.14. Summary of Maximum Total Phosphorus and Total Nitrogen Summer (April–September) Seasonal and Daily Loads for Attainment of Water Quality Standards in Echo Reservoir

	Total Phosphorus					**Total Nitrogen**				
	Current Load to Reservoir (kg/season)	**Allocated Load to Reservoir[1] (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**	**Delivery Ratio**	**Current Load to Reservoir (kg/season)**	**Allocated Load to Reservoir (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**	**Delivery Ratio**
Waste Load Allocations, Current										
Coalville WWTP (UPDES UT0021288)	165	249	1.4	51%	86%	715	2,200	12.1	208%	76%
Silver Creek WRF (UPDES UT0024414)	1,258	970	5.3	-23%	70%	11,343	9,837	54.0	-13%	71%
Park City tunnels (UPDES UT0025941; UPDES UT0025925)	4	4	0	0%	6%	53	53	0.3	0%	6%
Blue Sky Ranch (UPDES UT0025763)	N/A	15	0.1	N/A	70%	N/A	148	0.8	N/A	71%
Subtotal	*1,427*	*1,237*	*6.8*	*-13%*	–	*12,111*	*12,238*	*67.2*	*1%*	–
Waste Load Allocations, Reserved for Future Growth										
Silver Creek WRF (UPDES UT0024414)	–	485	2.7	–	70%	–	4,918	27.0	–	71%
Subtotal	–	*485*	*2.7*	–	–	–	*4,918*	*27.0*	–	–
MOS	–	**0**	–	–	–	–	**0**	–	–	–
Nonpoint source load allocation	**3,959**	**1,779**	**9.8**	**-55%**	–	**30,598**	**10,605**	**58.3**	**-65%**	–
Total load to reservoir	**5,387**	**3,502**	**19.2**	**-35%**	–	**42,709**	**27,761**	**152.5**	**-35%**	–

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

Table 6.15. Waste Load Allocations at Discharge Point for Wastewater Treatment Plants in the Rockport Reservoir for Summer Critical Season and Annual TMDLs

	Total Phosphorus (kg/season)					Total Nitrogen (kg/season)				
	Summer Allocated Load to Reservoir[1]	**Annual Allocated Load to Reservoir**	**Summer WLA at Discharge Location**	**Annual WLA at Discharge Location**	**Delivery Ratio**	**Summer Allocated Load to Reservoir[1]**	**Annual Allocated Load to Reservoir**	**Summer WLA at Discharge Location**	**Annual WLA at Discharge Location**	**Delivery Ratio**
Waste Load Allocations, Current										
Kamas WWTP (UPDES UT0020966)	183	366	277	554	66%	1,835	3,671	2,771	5,542	66%
Oakley WWTP (UPDES UT0020061)	120	241	173	346	70%	1,198	2,396	1,732	3,464	69%
DWR Kamas Fish Hatchery (general permit)	124	248	177	354	70%	802	1,603	1,162	2,324	69%
Francis WWTP (UPDES UTOP00202)	68	136	97	194	70%	669	1,338	970	1,940	69%
Waste Load Allocations, Reserved for Future Growth										
Oakley WWTP (UPDES UT0020061)	19	296	27	426	–	190	2,948	275	4,261	–
Francis WWTP (UPDES UTOP00202)	53	160	76	229	–	526	1,577	762	2,286	–

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

Table 6.16. Waste Load Allocations at Discharge Point for Wastewater Treatment Plants in the Echo Reservoir for Summer Critical Season and Annual TMDLs

	Total Phosphorus					Total Nitrogen				
	Summer Allocated Load to Reservoir[1]	**Annual Allocated Load to Reservoir**	**Summer WLA at discharge location**	**Annual WLA at discharge location**	**Delivery Ratio**	**Summer Allocated Load to Reservoir[1]**	**Annual Allocated Load to Reservoir**	**Summer WLA at discharge location**	**Annual WLA at discharge location**	**Delivery Ratio**
Waste Load Allocations, Current										
Coalville WWTP (UPDES UT0021288)	249	498	291	582	86%	2,200	4,400	2,909	5,819	76%
Silver Creek WRF (UPDES UT0024414)	970	1,940	1,385	2,771	70%	9,837	19,673	13,855	27,709	71%
Park City tunnels (UPDES UT0025941; UPDES UT0025925)	4	7	67	113	6%	53	71	830	1,115	6%
Blue Sky Ranch (UPDES UT0025763)	15	29	21	42	70%	148	295	208	416	71%
Waste Load Allocations, Reserved for Future Growth										
Silver Creek WRF (UPDES UT0024414)	485	1,455	693	2,078	–	4,918	14,755	6,927	20,876	–

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

6.4. Reasonable Assurance

Successful reduction in nonpoint source loading for both nitrogen and phosphorus is critical to the success of attaining water quality standards. As such, a watershed-based implementation plan has been developed for Rockport Reservoir and Echo Reservoir watersheds that will provide reasonable assurance that the stated nonpoint source reductions can be achieved. Specifically, the plan provides a detailed cost analysis and highlights priority actions and critical areas for nonpoint source implementation. Furthermore, the plan outlines technical and financial resources required to achieve nonpoint source implementation and a summary of projects and funding sources already in progress in the watershed. Stakeholders have demonstrated the ability to work together and successfully implement BMPs for a variety of sources, all of whom have been an integral part of the development of this TMDL and the accompanying implementation plan.

6.5. Seasonality

There are two important seasonal aspects to the Rockport Reservoir and Echo Reservoir TMDLs: 1) the critical season for oxygen depletion in the hypolimnia of the reservoirs and 2) the distribution of nutrient loads across seasons.

The critical season for oxygen depletion in the hypolimnia is the period in which the reservoirs are thermally stratified. It was assumed that the reservoirs are thermally stratified from May 15 to September 30. These dates were selected based on evaluation of all of temperature and DO profile data available for the reservoirs. DO and temperature profile data from the years 2004, 2007, and 2011 were used to further validate the use of this stratification season assumption for all of the conditions modeled.

Although the stratification period lasts for 137 days (May 15 through September 30), the critical season for nutrient loading to the reservoirs begins with the spring melt period, assumed to begin on April 1. Nutrient loads to the reservoir for the summer season used in the TMDL analysis extends from April 1 through September 30. The seasonal loads are important because spring runoff and summer storm events tend to generate the majority of sediment and nutrients from these watersheds. The reservoirs are drawn down significantly each fall and fill again in the spring. Nutrient loads from the watershed are minimal during the winter, which is not a critical period for algal growth or oxygen depletion in the reservoirs. Internal load typically represents load from previous years or seasons (e.g., winter) that is re-suspended and that contributes to summer nutrient concentrations at the surface. However, the inlet and outlet data from both reservoirs indicate that the reservoirs are a net sink for nutrients during the critical summer season. Therefore, no internal loading of nutrients to the reservoir surface is assumed for the summer stratification season.

The summer season used in the TMDL load analysis (April 1–September 30) is further divided into spring (April 1–July 15) and summer (July 15–September 30) components. Identifying when loads are delivered to the reservoir during the TMDL season is helpful in targeting implementation measures for nonpoint sources.

The nutrient load to Echo Reservoir is split relatively evenly between spring (April–mid July) and summer (mid July–September); however, the source of loads during these two seasons is significantly different (see Tables A-42 and A-43 in Appendix A). The majority of the Chalk Creek load occurs during the spring whereas the majority of the Weber River load occurs during the summer. This reflects the snow melt–dominated hydrology characterizing the Chalk Creek watershed in the spring and the release of water from Rockport Reservoir into the Weber River primarily during the summer season. While there is significant flow into Rockport Reservoir during the spring period, this flow is mostly being retained in Rockport Reservoir for release later in the summer season. The majority of the load to Rockport Reservoir is delivered during the spring melt period (see Tables A-44 and A-45 in Appendix A).

7. PUBLIC PARTICIPATION

Public participation was a large component of the TMDL process with several opportunities created for the specific purpose of gathering stakeholder input. Various public and working meetings coupled with watershed tours resulted in a high degree of public involvement that was critical for successful TMDL development (Table 7.1). These occasions included a variety of stakeholder groups including local municipalities, federal agencies, water districts, local landowners, and state agencies. Additionally, the TMDL document was made available to the public from November 18-December 20, 2013 in which several comments were received and incorporated (see Comment Matrix Appendix).

Table 7.1. Public Participation Events

Event	Dates	Agenda	Participants
Kickoff Meeting	February 22, 2012	Project outline and objectives, scheduling and milestones	•
Watershed Tour 1	April 11, 2012	Site visits to WWTPs, landfill, Chalk Creek, Wanship Dam	• Coalville • US Bureau of Reclamation • Summit County Health Department • Kamas Valley Conservation District • Weber Basin Water Conservancy District • Snyderville Basin Water Reclamation District • JUB Engineers
Watershed Tour 2	April 27, 2012	Site visits to Park City stormwater outfalls, Beaver Creek diversions, irrigation systems, septic systems in Tollgate Community	• Kamas Valley Conservation District • JUB Engineers •
Public Meeting	July 19, 2012	Data summary, Phase 2 modeling work, QA/QC plan review	• Snyderville Basin Water Reclamation District • Summit County Health Department • US Bureau of Reclamation • Kamas Valley Conservation District • USDA-NRCS • Blue Sky Ranch • Weber Basin Water Conservancy District • Summit County News • Park City Municipal Corporation

Table 7.1. Public Participation Events

Event	Dates	Agenda	Participants
Public Meeting	July 23, 2013		• Snyderville Basin Water Reclamation District • Summit County Health Department • Kamas Valley Conservation District • USDA-NRCS • Weber Basin Water Conservancy District • Carollo Engineers • Summit County Engineering • Division of Wildlife Resources • JUB Engineers
Final Public Meeting		Implementation Plan and Final TMDL Results Open house style	
Public Comment Period	November 18-December 20, 2013	TMDL made available for public input	

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Appendix A

Watershed and Reservoir Modeling

A-1. MODEL GOALS AND OBJECTIVES

Developing the Total Maximum Daily Load (TMDL) for the Rockport and Echo Reservoirs involved using two models: BATHTUB and Soil Water Assessment Tool (SWAT). BATHTUB is an empirical reservoir model developed by the US Army Corps of Engineers using data from over 500 reservoirs across the United States. SWAT is a watershed model developed by the US Department of Agriculture Agricultural Research Service (USDA-ARS). SWAT estimates nutrient loads from watershed sources and incorporates in-stream routing of sediment and nutrient loads. The models were used together to model nitrogen and phosphorus cycling, determine sources of loading for both nitrogen and phosphorus, and to model potential management scenarios. In particular, SWAT provides an estimate of watershed-generated nutrient inputs and inflow that can be used as inputs for the BATHTUB model. Conversely, output from the BATHUB model for Rockport Reservoir were used as inflow for the Echo Reservoir watershed SWAT model scenario runs.

The overall goals for the BATHTUB model are to generate estimates of existing nutrient loads and dynamics in the reservoir and to model scenarios to determine if management actions could reduce impairment in the reservoir by increasing dissolved oxygen (DO). Specific objectives include creating baseline reservoir models for nutrients and DO that represent 1) dry weather and low reservoir level conditions, 2) average weather and average reservoir level conditions, and 3) wet weather and high reservoir level conditions. Each of these sets of conditions has occurred since 2000. Scenarios that model different levels of nutrient input from the watershed, as well as changes in reservoir operation, were run and compared to the baseline model to determine the nutrient load reduction needed to meet water quality standards for DO.

The overall goal for the SWAT model is to provide data-driven estimates of the nutrient loads from various portions of the watershed. Nutrient loads and inflow generated by SWAT were used as inputs to BATHTUB. Additionally, these results identified sub-watersheds that contribute the highest proportion of nutrients to the reservoirs. SWAT outputs were used to develop a project implementation plan (PIP) and prioritize projects that will have the most impact on reducing nutrient loads to the reservoirs. Specific objectives include 1) generating estimates of total nitrogen and total phosphorus that reach the reservoir from subwatersheds (Figure A-1); 2) determining the load contribution from the following nonpoint sources: grazing, fertilizer, agricultural land, the Interstate 80 (I-80) and U.S. Route 40 (US-40) road corridors; and 3) determining nutrient loads from future growth and urbanization in the watershed.

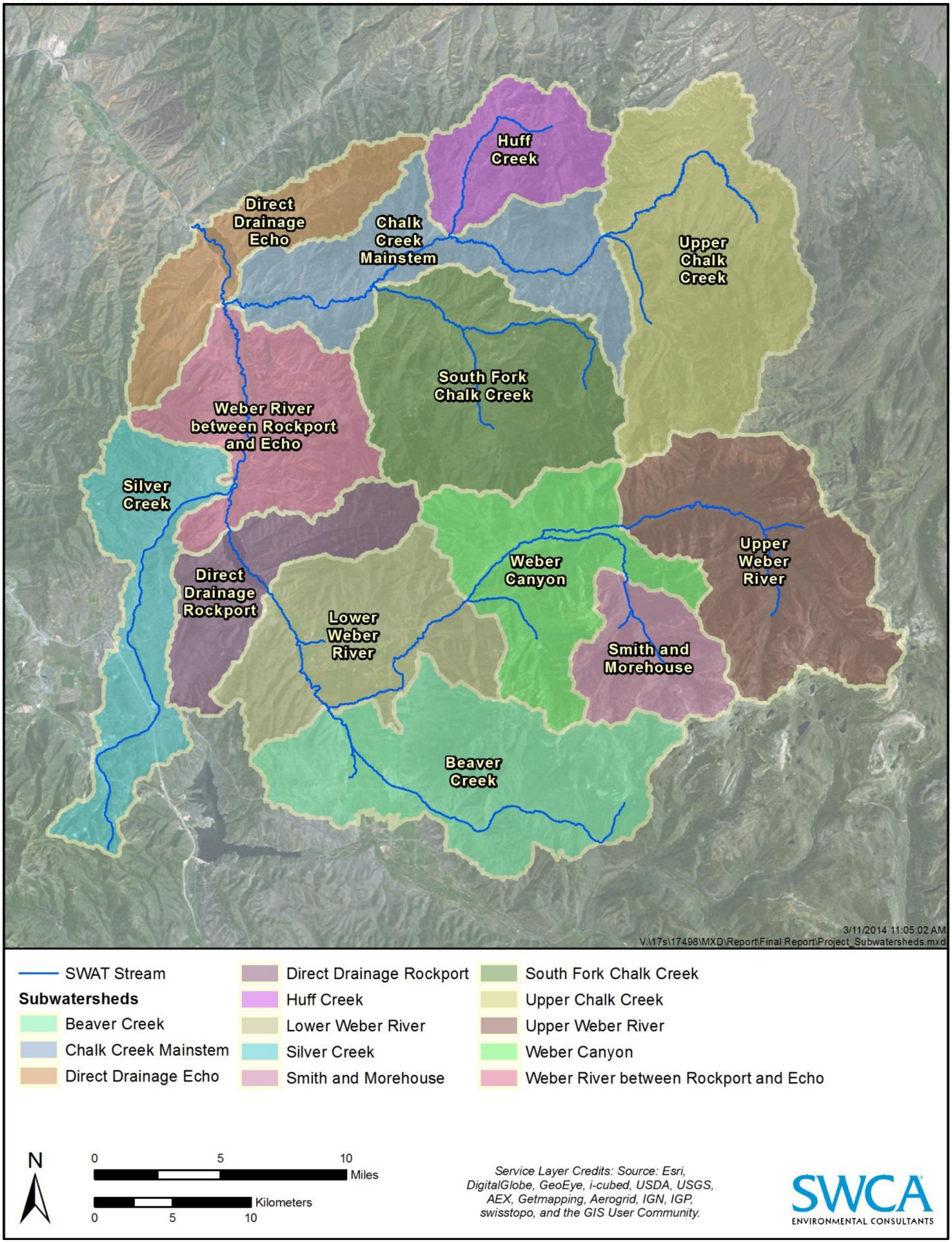

Figure A-1. Subwatersheds in the project area.

A-2. MODELED CONDITIONS

BATHTUB was set up to model representative dry (2004), average or expected normal (2007), and wet (2011) hydrologic conditions (Figure A-2). The SWAT models were set up to run from January 1, 1998, to December 31, 2011 in order to accommodate warm-up years (1998-2001). Warm-up years are the first years run in a model that allow it to initiate processes and are not used in the analysis in order to reduce the effects of initial model conditions on results. 2007 is considered an average year for stream flow and reservoir level, and is used for modeling average conditions in the project area.

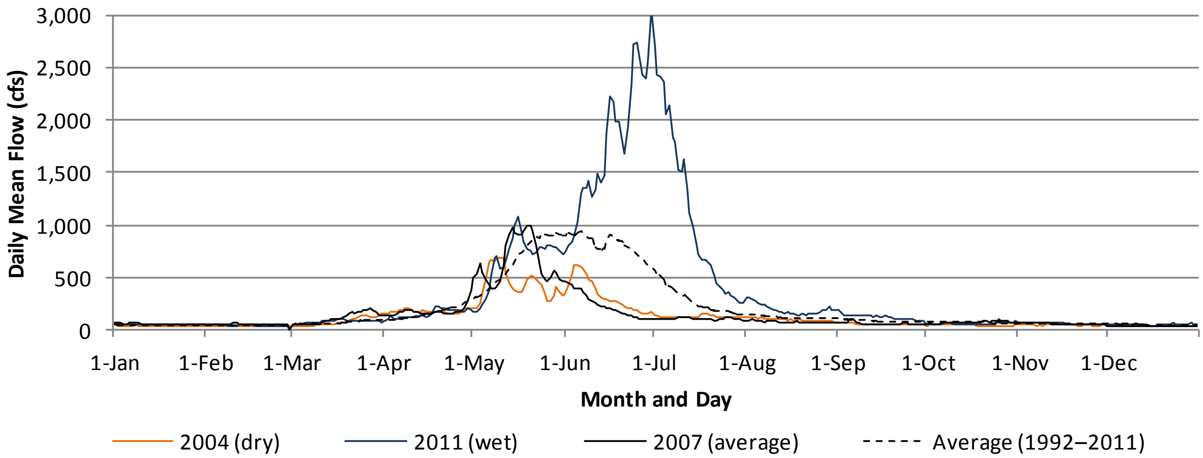

Figure A-2. Dry, wet, and average year hydrographs for the Weber River near Oakley, Utah (U.S. Geological Survey gage number 10128500).

A-3. WATERSHED MODEL: SOIL AND WATER ASSESSMENT TOOL

A-3.1 General Model Description

SWAT is used 'to predict the effect of management decisions on water, sediment, nutrient and pesticide yields with reasonable accuracy on large, ungaged river basins" (www.tamu.edu/SWAT). SWAT is an "interdisciplinary watershed modeling tool" (Gassman 2007) that has been used to conduct a variety of analyses including hydrologic studies, pollutant load assessments, climate change impacts, and support TMDL analyses (Borah et al. 2006, in Gassman 2007). The USDA-ARS created the SWAT model and continues to update the model and provide technical support for users. For the TMDL analysis, SWAT 2012 Version 591 was run using ArcGIS 10.0 SP5.

SWAT was used to assess known point sources and watershed/nonpoint source nutrient loading to the Weber River, Rockport Reservoir, and Echo Reservoir to support development of DO TMDLs for the reservoirs. Determining nutrient loads to the reservoirs is important because increases in nutrient levels can lead to nutrient enrichment and excessive plant growth (eutrophication), which strongly effects DO concentrations in the water column. The TMDL analysis used the hydrology and nutrient load components from SWAT to determine inputs to the reservoir from various sources.

The SWAT model incorporates data on climate, weather, land cover, land use, soils, topography, and known point sources to simulate hydrology and water quality parameters such as nutrients (nitrogen and phosphorus), pesticides, bacteria, erosion/sediment, algae, and DO. SWAT allows users to apply watershed-specific information about fertilization practices, grazing practices, irrigation, and septic systems to model nutrient loading from the watershed. The SWAT model also incorporates monitoring data from known point sources in the watershed such as the Silver Creek and Coalville City wastewater treatment plants. Since SWAT estimates discharge and nutrient loads on a subbasin level within the overall watershed, the SWAT model outputs may identify subbasins with high nutrient loads. This is useful in developing a targeted implementation plan that will meet the criteria for approval by the Water Quality Board and Environmental Protection Agency (EPA).

Weather data generates the hydrology in SWAT. Default weather station data are available in SWAT for the United States. However, the model is generally improved if precipitation and temperature data are provided from weather stations in or near the watershed (see Section A-3.2.3 for climate data used in the Rockport Reservoir watershed and Echo Reservoir watershed SWAT models). SWAT uses the weather data to account for several factors. 1) SWAT estimates evapotranspiration from the watershed; 2) SWAT accounts for snowmelt and snowfall effects with snow parameters, which are important in calibrating the timing of the snowmelt in the watershed and subsequent peak and baseflows; 3) SWAT has the ability to separate the watershed into bands based on elevation, which affects precipitation and air temperature. Groundwater and soil water are also components in the SWAT model, with input tables to adjust those portions of the hydrologic cycle. The USGS gage data and the USGS Baseflow Program algorithms were used to estimate baseflow, which is the contribution from groundwater to the stream.

Changes in hydrology from human actions are also simulated in SWAT, either through its point source feature or as a management operation. In SWAT, a point source is a way to add or subtract flow, sediment, and nutrients to a subbasin from a source that is not included in the land use or soil layers. Additional flow from a wastewater treatment plant is one example. However, the SWAT point source may also be used to remove water from a subbasin. The Weber-Provo diversion, which removes water from the watershed, is an example of a point source with negative flow values. Irrigation can be simulated using the management features in SWAT.

Reservoirs can also be included in a model to simulate the effects of storage and release on the hydrology of the watershed. Only the Smith and Morehouse Reservoir was included in the Rockport Reservoir watershed SWAT model since it affects flow from a subbasin coming into the Weber River. Rockport Reservoir and Echo Reservoir were intentionally left out because reservoirs are not well modeled in SWAT for water quality. Instead, reservoir water quality was modeled using BATHTUB.

SWAT organizes the input data within a watershed using what is called a hydrologic response unit (HRU). The subbasin, in addition to the land use, soils, and slope categories, defines the HRU. An HRU is composed of areas with the same land use, soils, and slope that will generate the same runoff. An HRU might consist of several areas in a subbasin that are not congruous, but they respond to a rainfall event in the same manner. An example of an HRU identifier is 1_ALFA_UT282_0-10, which indicates that this HRU is in subbasin 1, with a land use of alfalfa, soils classified as UT282, and slopes between 0 and 10%.

SWAT will model nutrient transport and transformations in the watershed through the soil, groundwater, and surface water. SWAT estimates loads of nitrogen and phosphorus contributed from traditional nonpoint sources such as soil and land use, but also management and point sources. Management sources include grazing and fertilizer application. Point sources can represent any type of additional nutrient load. The Rockport Reservoir and Echo Reservoir watersheds include point sources for wastewater treatment plants, fish hatcheries that discharge to a stream, and tunnels carrying stormwater and groundwater from another watershed. The point source inputs include loads for organic nitrogen, nitrite, nitrate, and ammonia as well as mineral phosphorus, and organic phosphorus. SWAT generates output for these nutrient forms on a reach scale.

SWAT models erosion and sediment yield using the Modified Universal Soil Loss Equation. It estimates erosion from hillslopes and channel erosion using rainfall intensity, land use, soil characteristics, and slope. SWAT accounts for both saturated and unsaturated flows. Saturated flow is driven by gravity and the movement is characterized by a storage routine method, which calculates the amount of soil water percolating to an underlying soil layer on a given day. Water in excess of the permanent wilting point or soil field capacity is available for plant growth or infiltration within the soil profile. For unsaturated flow, movement occurs in any direction based on energy gradients from areas of high to low water content. Only saturated flow is simulated; however, water consumed by the plant during growth is simulated indirectly by the evapotranspiration process associated with the plants.

A-3.2 Model Development for the Rockport Reservoir and Echo Reservoir Watersheds

A-3.2.1 General Model Setup

The project watershed contains both Rockport Reservoir and Echo Reservoir, which are located on the mainstem of the Upper Weber River (Figure A-1). For modeling purposes, two SWAT models were created for the TMDL analysis. The project area was split into the Rockport Reservoir watershed and the Echo Reservoir watershed based on the location of the Rockport Reservoir outlet. The watershed area upstream of and including Rockport Reservoir is considered Rockport Reservoir watershed. It includes the headwaters of the mainstem of the Weber River and Beaver Creek, a major tributary to the Weber River. The watershed area between the dam at Echo Reservoir and the dam at Rockport Reservoir is considered the Echo Reservoir watershed for SWAT modeling. Silver Creek and Chalk Creek are major tributaries that drain the Echo Reservoir watershed and flow into the Weber River above Echo Reservoir.

There are two reasons for creating the two SWAT models for the TMDL. First, the split allows the BATHTUB model results for Rockport Reservoir to be easily incorporated into the Echo Reservoir watershed SWAT model as a release from Rockport Reservoir into the downstream watershed, and provides a simple way to incorporate BATHTUB for in-reservoir and reservoir operations modeling. Second, measured outflow data exist for Rockport, which eliminates the need to model and calibrate Rockport Reservoir releases as part of the hydrology in SWAT, thereby removing the uncertainty associated with simulating reservoir releases.

SWAT was set to run for the time period between 1998 and 2011 on a monthly timestep. The first four years were ignored as described above. 2007 is considered an average year, 2004 represents a dry year, and 2011 represents a wet year. Much of the example data presented in this document represents average conditions from 2007.

A-3.2.2 Hydrologic Response units

As mentioned, SWAT characterizes the watershed by generating a HRU. A HRU is defined by the subbasin, land use, soil type, and slope class. From these inputs, the HRU is given specific characteristics that determine the amount of runoff generated from a storm event. Within a subbasin, there can be multiple HRUs. The HRUs are “virtual” in the sense that the only spatial reference is the subbasin. The runoff and nutrient load generated for all HRUs is summed at the outlet of each subbasin. The total represents the entire subbasin. Therefore, SWAT does not account for the location of an HRU relative to the stream within a subbasin, but does account for the location of subbasins relative to each other for routing purposes.

A-3.2.2.1 SUBBASIN DELINEATION

The total project area consists of the combined Echo and Rockport watersheds since Rockport releases are transported to Echo Reservoir via the Weber River. However, for modeling purposes the Echo Reservoir watershed and Rockport Reservoir watersheds were split into subbasins based on the stream network, locations of gages for calibration, and locations of known point sources (Figure A-3). If the modeler chooses, the SWAT program will automatically generate subbasins and streams within the watershed using the digital elevation model (DEM) based option. This option was chosen to ensure that subbasins contained only one known point source discharge (with the exception of the Park City tunnels, which were combined into a single point source), and to split large subbasins that drain into small subbasins. Subbasin boundaries were also adjusted to have each reservoir contained within a single subbasin.

Next, the DEM-generated subbasins option was used to generate a stream network along with the subbasins. These stream shapefiles were then adjusted to better fit the modified subbasins described above. The Silver Creek channel was extended into the upper watershed, and the Chalk Creek channel was extended into the upper Echo Reservoir watershed to include a smaller headwater channel not included in the SWAT-generated streams shapefile (Figure A-3).

A-3.2.2.2 LAND USE INPUTS

A land use map was compiled for SWAT from several sources (Figure A-4). The Water Related Land Use (WRLU) dataset was combined with the 2006 National Land Cover Database (NLCD) into a single land use layer for the entire project watershed and used in both the Rockport Reservoir watershed model and the Echo Reservoir watershed model. Land use descriptions from the WRLU were used where available because they are more detailed than NLCD. The NLCD was used in areas where WRLU was not available. Information on irrigation type (flood or sprinkler) was incorporated with the land use descriptions using the four-digit codes supplied in the SWAT database. To account for the sprinkler and flood irrigation, new land use categories were added to the crop table in the SWAT database. These new land use categories are the same as the existing land use, but coded differently to reflect the irrigation type (i.e., flood, sprinkler, or no irrigation) (Table A-1). If no information on the type of irrigation was available, as was the case for any areas defined with the NLCD dataset, then the SWAT code was assigned.

The land use layer and SWAT databases were also modified to incorporate a land use type for the I-80 and US40 corridors file to identify nutrient load contributions from these major roads in the project area. A road footprint was estimated by measuring the road width at five locations in the project area, calculating an average width, and applying it to the appropriate subbasins. These roads only pass through the Echo Reservoir watershed and have no effect within the Rockport Reservoir watershed.

The land use layer and SWAT database were also modified to indicate areas of barren, forest, or range (brush and grass) that are within an existing U.S. Forest Service (USFS) grazing allotment (Table A-1) to differentiate between areas privately and publicly grazed. This adjustment only affects the Rockport Reservoir watershed, where both public and private grazing occur in several subbasins. Only a small portion of the Echo Reservoir watershed area is within a USFS allotment, so public grazing is considered negligible in the Echo Reservoir watershed.

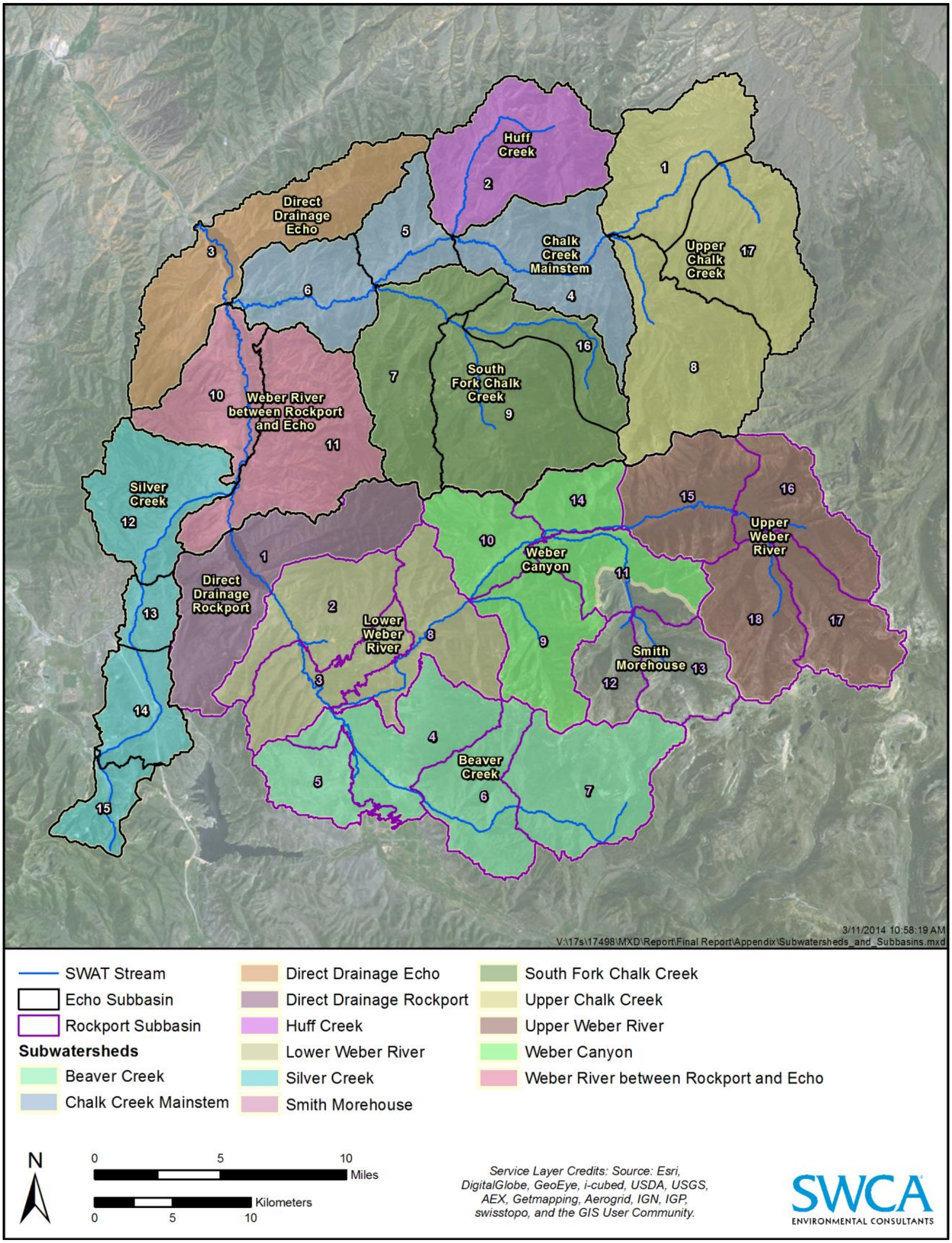

Figure A-3. The SWAT model subbasins and SWAT-generated streams for the Rockport Reservoir and Echo Reservoir watersheds.

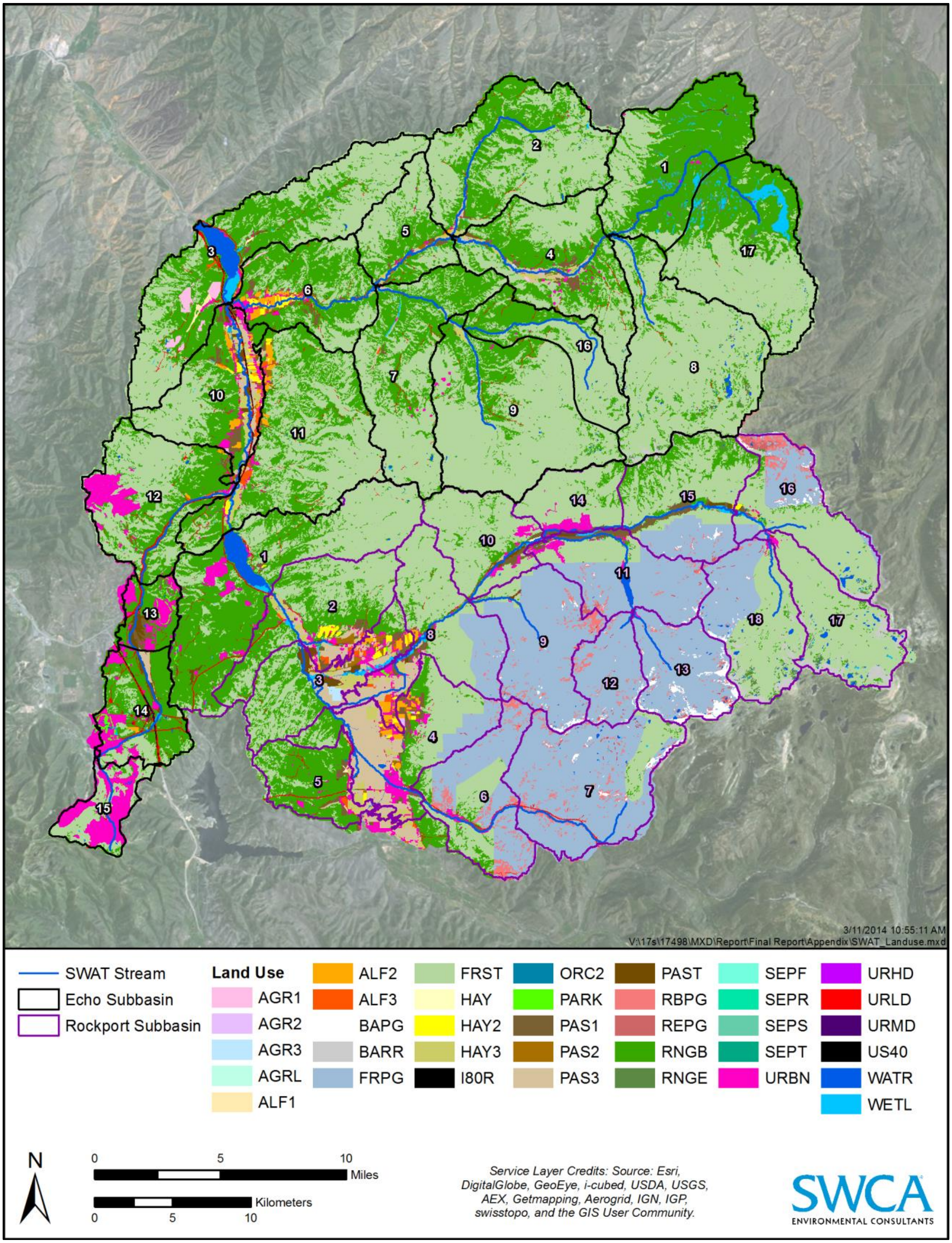

Figure A-4. SWAT land use map.

To run population growth scenarios for the TMDL, small portions consisting of approximately 1 acre of each subbasin were digitized as urban-low density (URLD), urban medium density (URMD), and urban high density (URHD). These modifications occurred only if the land use types did not already exist in the subbasin. These areas are on the order of tens of acres—too small to noticeably affect the model. They simply act as placeholders for running scenarios involving urbanization within the watershed for the TMDLs.

Table A-1. Land Use Descriptions and Reclassification Codes

SWAT Class	SWAT Code	Original Description	Original Data Source
Agricultural – Not Irrigated	AGR1	Dry Grain/Seeds Fallow – Irrigated Land	WRLU
Agricultural – Sprinkler	AGR2	Grain	WRLU
Agricultural – Flood Irrigated	AGR3	Grain	WRLU
Cultivated Crops	AGRL	Cultivated Crops	NLCD
Alfalfa – Not Irrigated	ALF1	Dry Alfalfa	WRLU
Alfalfa – Sprinkler	ALF2	Alfalfa	WRLU
Alfalfa – Flood Irrigated	ALF3	Alfalfa	WRLU
Barren Land	BARR	Barren Land (Rock\Sand\Clay)	NLCD
Mixed Forest	FRST	Deciduous Forest Evergreen Forest Mixed Forest	NLCD
Hay	HAY	Grass Hay	NLCD
		Grass Hay – Subirrigated	WRLU
Hay – Sprinkler	HAY2	Grass Hay – Sprinkler	WRLU
Hay – Flood Irrigated	HAY3	Grass Hay – Flood irrigated	WRLU
Orchard – Sprinkler	ORC2	Orchard – Sprinkler	WRLU
Pasture – Not Irrigated	PAS1	Dry Idle Dry Pasture Idle – Irrigated Land Range Pasture	WRLU
Pasture – Sprinkler	PAS2	Pasture – Sprinkler	WRLU
Pasture – Flood Irrigated	PAS3	Pasture – Flood Irrigated	WRLU
Pasture	PAST	Pasture – Subirrigated Idle – Irrigated Land	WRLU
		Pasture/Hay	NLCD
Range – Not Irrigated	RNGB	Shrub/Scrub	NLCD
Urban – Not Irrigated	RNGE	Grassland/Herbaceous	NLCD
Urban	URBN	Urban	NLCD
		Urban – Flood	WRLU
Urban High Density	URHD	Developed – High Density	NLCD
Urban Low Density	URLD	Developed – Low Density	NLCD
Urban Medium Density	URMD	Developed – Open Space	NLCD

Table A-1. Land Use Descriptions and Reclassification Codes

SWAT Class	SWAT Code	Original Description	Original Data Source
Water – Not Irrigated	WATR	Water Lakes and Ponds	NLCD
		Open Water Reservoirs Sewage Lagoon Streams	WRLU
Wetland – Not Irrigated	WETL	Emergent Herbaceous Wetlands Woody Wetlands	NLCD
Interstate 80 Corridor	I80R	Interstate 80 Corridor	User Defined
U.S. 40 Corridor	US40	U.S. 40 Corridor	User Defined
Parks – Sprinkler	PARK	Urban Grass/Parks	NLCD
Barren, within a public grazing allotment	BAPG	Barren (NLCD) intersected with USFS grazing allotment map	NLCD USFS Grazing Allotment
Forest with public grazing allotment	FRPG	Mixed Forest (NLCD) intersected with USFS grazing allotment map	NLCD USFS Grazing Allotment
Range (grass) with public grazing allotment	REPG	Grassland/Herbaceous(NLCD) intersected with USFS grazing allotment map	NLCD USFS Grazing Allotment
Range (brush) with public grazing allotment	RGPB	Shrub/Scrub (NLCD) intersected with USFS grazing allotment map	NLCD USFS Grazing Allotment

A-3.2.2.3 SOILS

The State Soil Geographic (STATSGO) soils dataset was used for the SWAT model because Soil Survey Geographic (SSURGO) data, although available for portions of the watershed, were missing in large areas of the Rockport Reservoir watershed, primarily in USFS lands (Figure A-5). Soils within the Echo and Rockport Reservoir watershed and their associated erodibility factor are listed in Table A-2.

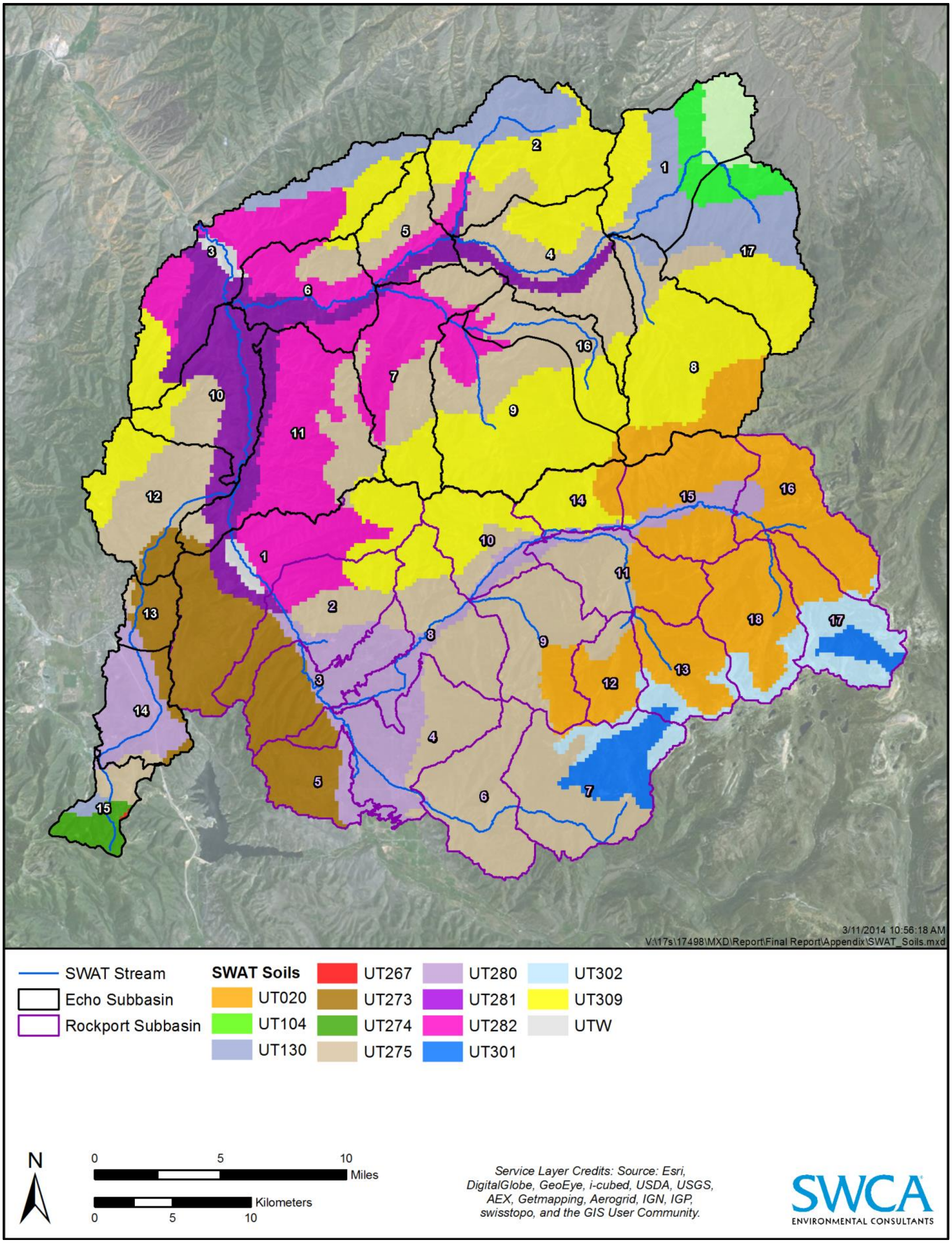

Figure A-5. SWAT soils map showing STATSGO state map unit identification (STMUID) numbers.

Table A-2. Soils in the Rockport and Echo Reservoir Watershed and Associated Erodibility Factor

Soil Group	Soil State Map Unit Identification Code	Soil Surface Texture	Soil Erodibility (K factor) of First Layer
FLUETSCH	UT020	Sandy loam	33.6
KEARL (in Utah)	UT104	Loam	22.8
ANT FLAT	UT130	Loam	14.1
ROUNDY	UT267	Loam	8.8
BROADHEAD	UT273	Loam	15.2
POLELINE	UT274	Gravelly loam	12.8
MANILA	UT275	Loam	26.4
KOVICH	UT280	Loam	12
PRINGLE	UT281	Loam	48-52.8
RICHSUM	UT282	Silty loam	2.8-2.5
SKUTUM	UT309	Loam	43.2
KEARL (in Wyoming)	WY349	Loam	14.4

Initial soil nutrient concentrations were adjusted from SWAT default values based on two existing sources: 1) a phosphatic shale layer that contributes to soil phosphorus concentrations in both the Rockport Reservoir and Echo Reservoir watershed (Figure A-6), and 2) long-term agricultural activities that have altered soil nutrient concentrations in areas where grazing and farming occur. Both of these sources produce labile phosphorus: the fraction of phosphorus loosely attached to soil and easily converted to other forms. Concentrations of labile phosphorus from these sources were estimated using literature values, measured soil phosphorus concentrations, and rock phosphorus data.

The labile soil phosphorus for the upper two soil layers on agricultural areas was determined using values reported in existing literature. Hay, alfalfa, and pasture were given a value of 25 milligrams of phosphorus per kilogram soil (mg P/kg) (Arnold et al. 2011) in the first two soil layers. The lower soil layers remained at the default value.

Soils classified as UT282 (named Richsum) were given a value of 100 mg P/kg soil. This value is based on a soil sample taken from the Richsum soil in the Fish Creek drainage area of the Chalk Creek watershed.

For the forest, range, and barren land uses and soils, initial values for soil labile phosphorus for other areas were modified based on the percentage of rock phosphorus in the geologic formation. This calculated value was only used if the HRU was not already defined using the previously described protocols. The soil labile P was estimated from percent rock phosphorus by first pairing the SWAT default value for soil labile phosphorus (5 mg/kg soil) with the median rock phosphorus percentage (0.163%). For each value of percent rock phosphorus above 0.163%, a proportional increase was calculated and then applied to the SWAT soil labile phosphorus default value (Table A-3). If the percent rock phosphorus value was less than 0.163%, the SWAT default of 5 mg/kg for soil labile phosphorus was used. The default SWAT value of 5 mg/kg soluble phosphorus was used for all other land uses including those classified as urban, include parks, septic areas, and wetlands.

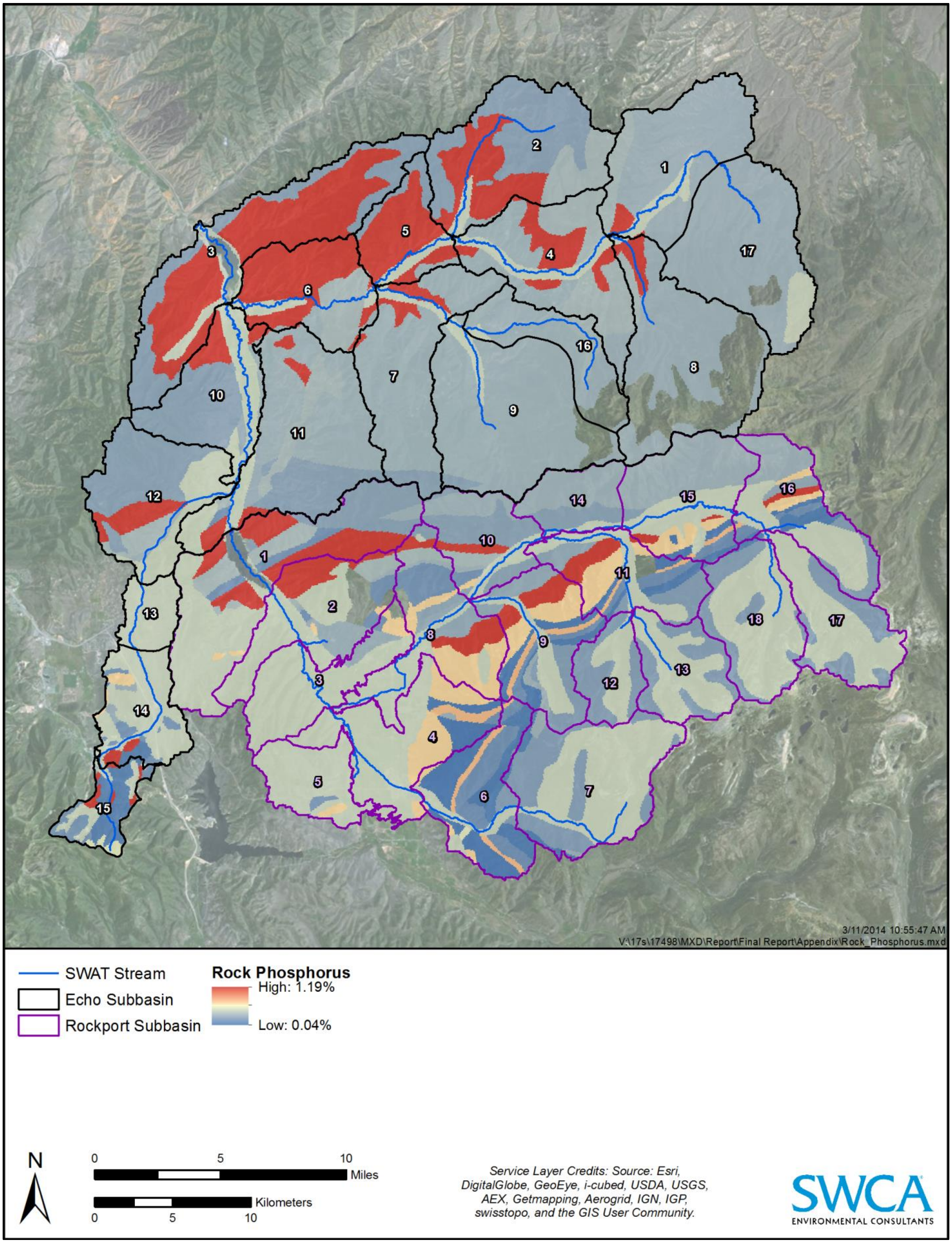

Figure A-6. Percent rock phosphorus in the Rockport Reservoir and Echo Reservoir watersheds.

Table A-3. Rock Phosphorus Percentages and the Resulting Value Used in SWAT for Initial Labile Phosphorus Concentrations (mg/kg)

Rock Phosphorus Percentage	Proportional Increase to Default Soils	Value (mg labile P/kg soil)
0.163	0.00	5.0
0.165	0.01	5.0
0.180	0.10	5.5
0.220	0.35	6.7
0.316	0.94	9.7
0.535	2.27	16.4

Since each HRU may consist of several polygons that intersect areas of differing rock phosphorus, an area-weighted average was calculated to determine a labile phosphorus value for each HRU in the Echo Reservoir watershed.

The SWAT model was then run using the estimated soil labile P values, default SWAT values for soil nitrate, soil organic nitrogen, soil organic phosphorus, and the soil carbon default concentrations to determine initial conditions for soil nitrate, organic nitrogen, organic phosphorus and total phosphorus. The SWAT output for soil nutrients was used as initial soil concentrations for nitrate and total nitrogen. (Because the SWAT output is in units of kg/ha, the values were converted to SWAT input units of mg/kg soil using soil depth, HRU area, and bulk density). Each soil may have up to four layers. Because organic nitrogen is present mostly at the surface, it was calculated only for layers 1 and 2. Nitrate was calculated for all layers available for each soil because of its high mobility. The same method was used to generate initial soil conditions for organic P. All initial soil nutrient concentrations were a primary calibration parameter that were adjusted across the watershed to generate model output consistent with measured spring nutrient loads (Table A-4). In addition to adjusting soil nutrients, SWAT allows users to define nitrogen and phosphorus concentrations in the channel. The nitrogen values were not modified. The subbasin average soil labile P (using the soil labile P values calculated using percent rock phosphorus) was used as these inputs.

Table A-4. Initial Soil Nutrient Concentrations

Soil Type	Nitrate (mg/kg)		Organic N (mg/kg)		Soluble P[1] (mg/kg)		Organic P (mg/kg)	
Watershed	Rockport	Echo	Rockport	Echo	Rockport	Echo	Rockport	Echo
UT020	0.1-0.4	0.2	40	113	2.4-3.6	6.0	7.5	46
UT104	-	0.1	-	1,089	-	6.0 - 30.0	-	443
UT130	-	0.4 – 0.6	-	387- 663	-	1.3 -30.0	-	80 - 269
UT267	-	0.3	-	830	-	5.0-5.3	-	337
UT273	0-0.9	0.2 – 0.3	0-774	555-793	2.3-5.0	1.3-25.0	0-145	115- 323
UT274	-	0.6	-	838.2	-	5.0	-	340
UT275	0.2-0.4	0.2- 0.3	220	360- 617	2.4-3.8	1.3- 30.0	41	75-251
UT280	0.4-0.9	0.4	642	1,502	2.4-4.8	5.0- 25.0	120	610
UT281	0.3-0.8	0.5	774	1266- 2,171	2.3-4.5	1.3-30.0	145	262- 881

Table A-4. Initial Soil Nutrient Concentrations

Soil Type	Nitrate (mg/kg)		Organic N (mg/kg)		Soluble P[1] (mg/kg)		Organic P (mg/kg)	
UT282	0.2-0.5	0.2-0.3	176	288-493	3.2	25.0-120.0	33	60- 201
UT301	0.1-0.3	-	40	-	2.4-3.6	-	7.5	-
UT302	0.1-0.3	-	40	-	2.4-3.6	-	7.5	-
UT309	0.5-0.6	0.4-0.7	453	741-1,270	2.4-2.6	1.3-12.0	85	153-515
UTW	0	0	0	0	2.4	1.3- 30.0	0	0
WY349	-	0	-	1,027	-	6.0- 30.0	-	417

[1] A value of 25.00 mg/kg was used for all agricultural land uses.

A-3.2.2.4 SLOPES

SWAT allows users to define up to five slope classes. The models for Rockport Reservoir and Echo Reservoir watersheds include four slope classes: 0–10%, 10–20%, 20–35%, and greater than 35%. The 0–10% classification contains most of the agricultural areas since the 10–20% class is limited in its irrigation capacity. The final two classifications represent areas with increasing potential for erosion, with slopes greater than 35% generally occurring in the steeper mountain areas at higher elevations (Figure A-7).

A-3.2.3 Climate Inputs

Climate data were obtained from the Utah State University Climate Center website (climate.usurf.usu.edu) for the period between January 1, 1998, and May 31, 2012 (Table A-5) for several weather stations in or near the watershed. Data obtained consisted of minimum daily temperature, maximum daily temperature, and precipitation. The same precipitation and temperature datasets were used for both the Rockport Reservoir and Echo Reservoir watershed models because SWAT chooses a weather station based on location (Figure A-8) to generate weather data for each subbasin, which generates weather statistics that the model uses for calculations.

Table A-5. Weather Stations used in the SWAT Model

Weather Station Name	Weather Station Code	Data Used for Each Watershed	Latitude	Longitude	Elevation (m)
Coalville	USW00024120	Precipitation (R, E), Temperature (R, E)	40.914	-111.398	1,691.6
Coalville 13 East	USC00421590	Precipitation (R, E), Temperature (R, E)	40.938	-111.147	1,984.2
Kamas	USC00424467	Precipitation (R,E), Temperature (R, E)	40.649	-111.285	1,973.6
Echo Dam	USC00422385	Precipitation (R, E), Temperature (R, E)	40.966	-111.435	1,665.7
Park City 1.3 East	US1UTSM0004	Precipitation (E)	40.656	-111.469	2,244.5
Snyderville	USC00427942	Precipitation (E)	40.704	-111.537	1,969.0
Wanship Dam*	USC00429165	Precipitation (R), Temperature (R)	40.791	-111.408	18,10.96

* Wanship Dam is now Rockport Dam.

† R=Rockport, E=Echo

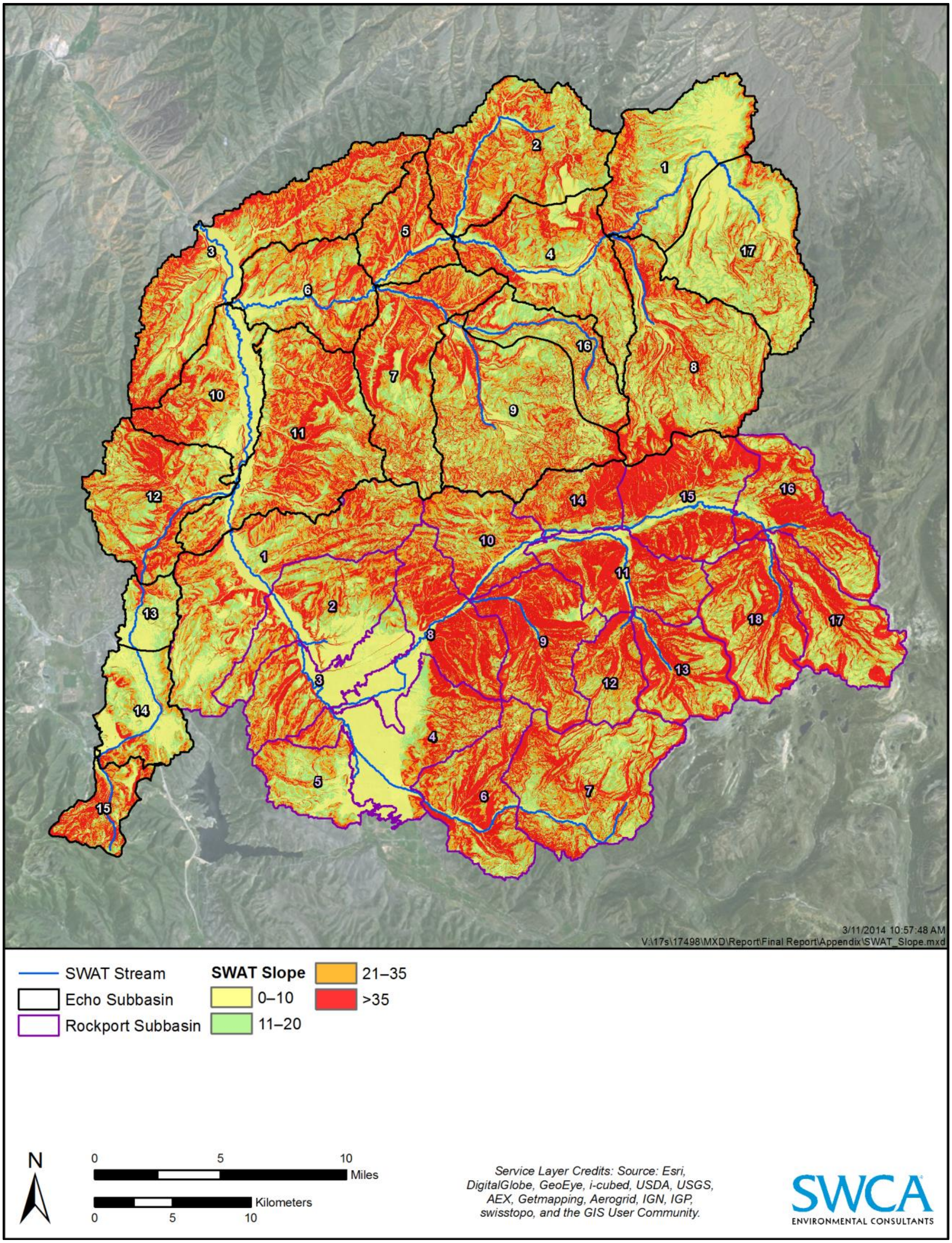

Figure A-7. SWAT-generated slope classes.

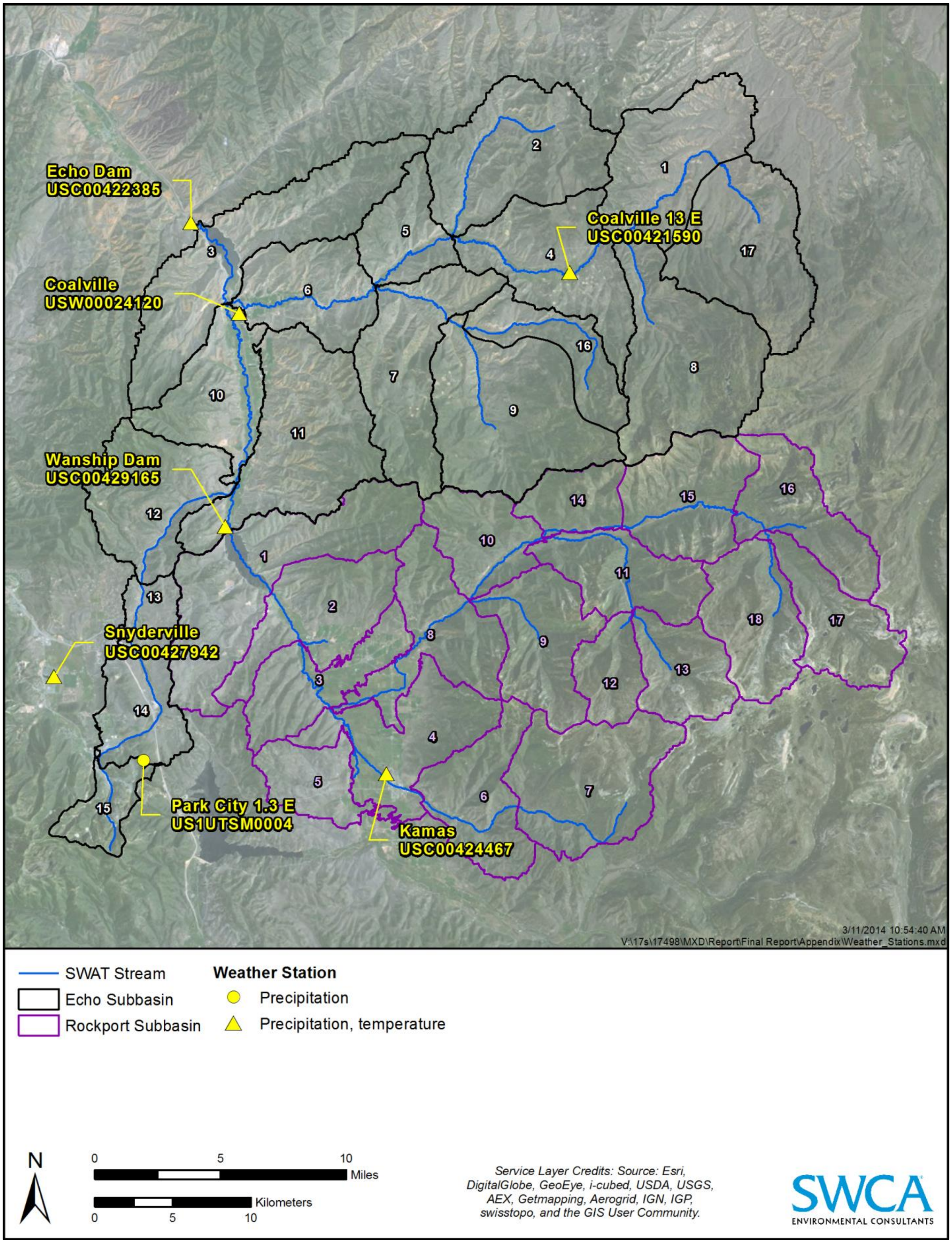

Figure A-8. Location of weather stations accessed for temperature and precipitation data for SWAT.

A-3.2.4 Irrigation inputs

Irrigation activities in the watershed include sprinkler irrigation, flood irrigation, and inter-basin transfers. The Utah Division of Water Rights supplied flow data for known and gaged diversions (Figure A-9). The diversion data were compiled to estimate a total volume of water used for irrigation within each subbasin. Irrigation is included in the model as a management option. For the inter-basin transfers, the Weber-Provo diversion takes water out of the Weber River and delivers it to the Provo River watershed, outside the project watershed. The measured diversion from Weber to Provo was used as a direct input to the hydrologic portion of the SWAT model.

Irrigation rates (mm/day) were developed for each land use and subbasin for specific years based on measured irrigation diversion data for each subbasin (Tables A and B; UDWR 2013) and the range of application rates for sprinkler and flood irrigation provided by Thomas Hoskins in the Natural Resources Conservation Service (NRCS) Coalville Field Office. The total acreage in each subbasin that is irrigated by either flood or sprinkler was obtained from the Water Related Landuse Layer. Generally, the amount of water diverted was assumed to be the same as the amount applied as irrigation, except in cases where the diverted volume exceeded the maximum recommended irrigation rates (24 millimeters per day for sprinkler, and 300 mm/day for flood). A summary of irrigation rates for 2007, the average hydrologic year, is provided in Tables A-6 and A-7 in the units used by the SWAT model (mm/day).

Irrigation diversions were assigned to the most appropriate subbasin based on known irrigation demand and specific monthly diversion rates. Generally, water withdrawn was applied to the subbasin from where it was diverted or to adjacent, downstream subbasins that contain irrigated land uses. In some cases, up-gradient subbasins were irrigated by sprinklers assumed to be under pressure. A summary of the diversions used to irrigate each subbasin is also provided in Tables 7 and 8. SWAT inputs are in millimeters of water, so the acre-feet from the diversion data were converted to millimeters through the total acreage of HRUs within the subbasin to convert the acre-feet of water to millimeters per day (Tables A-8 and A-9).

In addition to providing a range of irrigation rates, the NRCS office in Coalville, Utah, also supplied information on irrigation efficiency and a qualitative assessment of runoff from irrigated lands (low versus high), which SWAT also incorporates in the operations/management file. Irrigation efficiencies were assumed to be 30% for flood-irrigated land and 70% for sprinkler-irrigated land. Surface runoff was assumed to be high for flood-irrigated land and low for sprinkler-irrigated land.

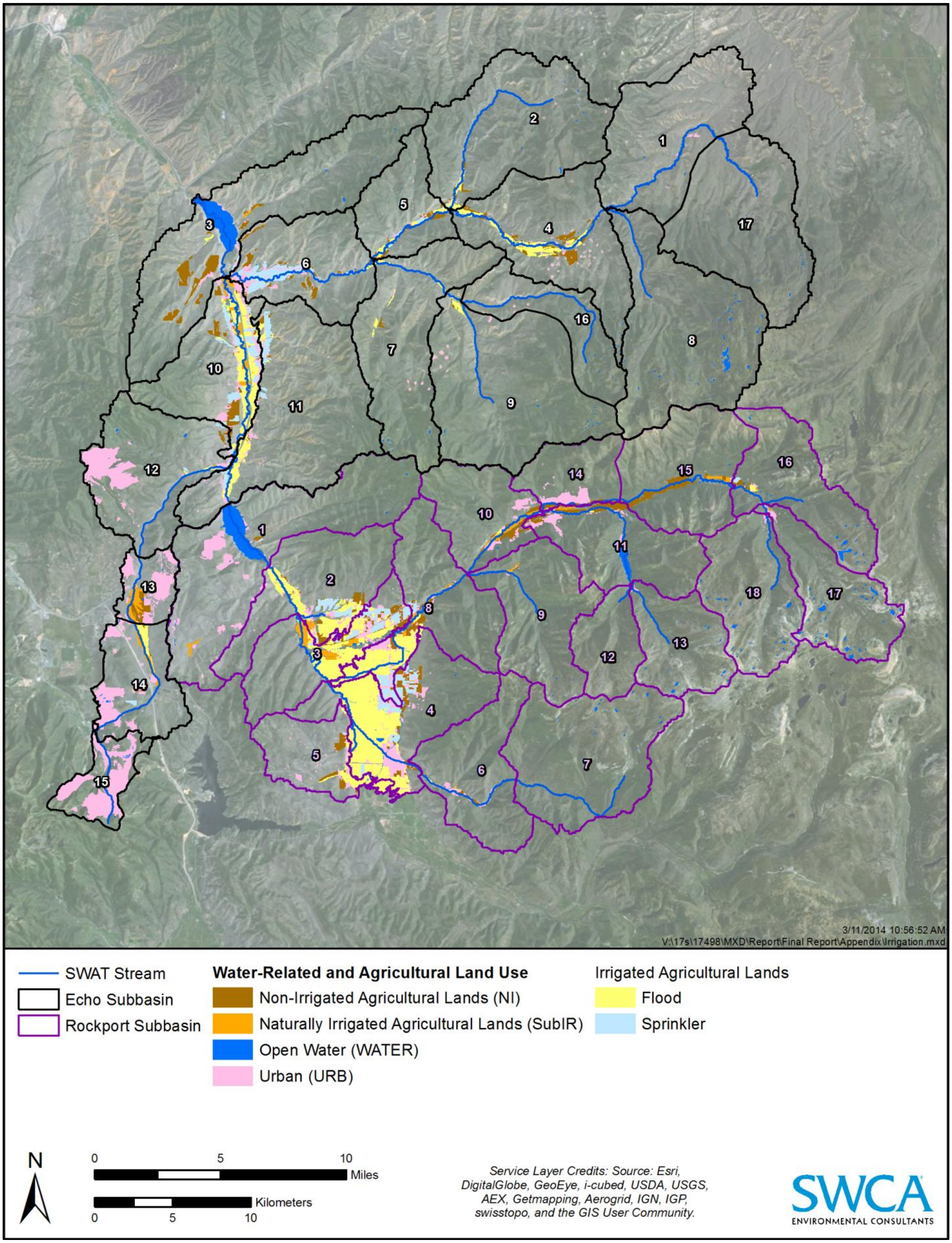

Figure A-9. Location of sprinkler and flood irrigation areas and locations of known diversions.

Table A-6. Monthly Diverted Irrigation Values (Acre-Feet) in Irrigated Subbasins for Rockport Reservoir Watershed

Diversion Subbasin	Irrigated Subbasin	May	June	July	August	September
3	1,2	1,040	1,000	268	240	36
8	3–10	4,900	4,772	396	690	72
11	11–19	150	80	–	–	–

Table A-7. Monthly Diverted Irrigation Values (Acre-Feet) in Irrigated Subbasins for Echo Reservoir Watershed

Diversion Subbasin	Irrigated Subbasin	May	June	July	August	September
4	2,4,7,9	858	806	224	168	131
6	5,6	590	696	374	366	354
10	3,10	1,856	1,852	451	918	925
11	11–12	860	943	644	614	207

Table A-8. Modeled Irrigation Types for Rockport Reservoir Watershed Subbasins and Month as Millimeters Applied Per Day

Subbasin	Irrigation Type	May	June	July	August	September
3	Flood	119.0	115.0	26.7	23.2	–
3	Sprinkler	12.0	12.0	12.0	12.0	9.5
8	Flood	86.0	84.0	3.6	8.8	–
8	Sprinkler	6.0	6.0	12.0	12.0	4.4
11	Flood	175.0	175.0	–	–	–
11	Sprinkler	18.0	18.0	–	–	–

Table A-9. Modeled Irrigation Types for Echo Reservoir Watershed Subbasins and Month as Millimeters Applied Per Day in 2007

Subbasin	Irrigation Type	May	June	July	August	September
4	Flood	120.0	113.0	31.2	23.5	18.2
4	Sprinkler	20.0	12.0	12.0	12.0	12.0
6	Flood	140.0	172.0	83.0	75.0	72.0
6	Sprinkler	12.0	12.0	10.0	12.0	12.0
10	Flood	176.0	175.0	47.5	93.0	94.0
10	Sprinkler	24.0	24.0	–	5.0	4.0
11	Flood	197.0	212.0	157.0	150.0	36.5
11	Sprinkler	16.0	20.0	5.0	5.0	12.0

A-3.2.5 Reservoir Releases

Release of water from Rockport Reservoir is a major input to the Echo Reservoir watershed. Additionally, Smith Morehouse Reservoir releases water to the Weber River upstream of Rockport Reservoir, which is also an important input to the watershed. Because both Rockport and Smith and Morehouse are managed releases, daily flow release data are available and used as direct inputs to the SWAT model. Water quality from each reservoir is estimated using available data from the reservoir itself, or in the case of Rockport release, in the Weber River below.

A-3.2.5.1 ROCKPORT RELEASES

The U.S. Bureau of Reclamation (BOR) provided flow release data from Rockport Reservoir and the UDWQ provided water quality data. Where water quality data are not available for a specific month, either the monthly or seasonal average across the entire dataset (1998–2011) was used. Only data for 2007 are shown in the table below (Table A-10). Remaining input data are available in spreadsheet form.

Table A-10. 2007 Flow and Water Quality Data (mg/L) for Rockport Reservoir as Monthly Averages or Seasonal Averages

Flow (cfs)	Ammonia –N	Dissolved Oxygen	Inorganic –N	Organic Nitrogen	Phosphate-Phosphorus	Total Suspended Solids (TSS)
76.50	0.03	26.09	0.32	0.65	0.020	5.87*
68.79	0.04	11.66	0.22	0.35	0.023	5.87*
43.72	0.03	11.50	0.11	0.42*	0.028	5.87*
46.67	0.03	9.78	0.45	0.42*	0.020	4.00
109.33	0.04*	10.99	0.20*	0.48*	0.021	8.65
224.55	0.06	9.45	0.13	0.48*	0.035	4.80
213.84	0.04*	5.80	0.27	0.48*	0.050	4.80
206.98	0.03	5.69	0.29	0.48	0.067	10.58*
176.24	0.03	5.38	0.18	0.38	0.038	10.58*
94.18	0.03	5.49	0.20*	0.48*	0.043	9.29
85.55	0.03	8.83	0.44*	0.25	0.02*	8.00
85.75	0.03	11.59	0.15	0.42*	0.020	5.60

* Indicates average is seasonal.

A-3.2.5.2 SMITH AND MOREHOUSE RELEASES

Since the Smith and Morehouse Reservoir releases water into the Weber River system, it was included in the Rockport Reservoir watershed SWAT model to better calibrate the hydrology. The Weber Basin Water Conservancy District provided monthly reservoir outflow data. Water quality data available from UDWQ were used to estimate initial reservoir water quality conditions: nitrate (0.05 milligrams per liter [mg/L]), ammonia (0.0392 mg/L), organic phosphorus (0.005 mg/L), and soluble phosphorus (0.005 mg/L). Other inputs left as default values and monthly releases from the reservoir are shown in Table A-11. The other reservoirs are modeled in BATHTUB and therefore are not included in the SWAT model.

Table A-11. 2007 Monthly Releases from Smith and Morehouse Reservoir

Release	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Acre-feet	706	704	1,220	880	12,700	630	2,030	1,890	740	310	300	198
cfs	11.4	12.6	19.7	14.7	204.8	10.5	32.7	30.5	12.3	5.0	5.0	3.2

A-3.2.6 Grazing

Grazing, primarily of cows and sheep, is a common agricultural activity in the Rockport Reservoir and Echo Reservoir watersheds. In the Rockport Reservoir watershed, grazing occurs on both private property and public USFS-managed grazing allotments. In the Echo Reservoir watershed, all land except a small portion of a USFS allotment is privately owned. Therefore, only private grazing is considered present in the Echo Reservoir watershed. SWAT inputs related to grazing impacts were estimated from the total number of animal units within a subbasin and land use.

The Uinta-Wasatch-Cache National Forest office and the Heber Ranger District office in Kamas, Utah, provided information on public grazing use for each USFS allotment in the Rockport Reservoir watershed. Data available include the allotment locations in a geographic information system (GIS) layer and permit documents describing the allotment and grazing permit conditions. The permit documents contain information about the number and type of animals as well as the dates that the allotment can be grazed. Employees from the NRCS at the Coalville office supplied information on private grazing, including estimates of the animal units by season in the watershed zones (Figure A-10) for both Rockport Reservoir and Echo Reservoir watersheds.

Grazing numbers from the 2011 USFS allotment permits were assumed typical for those allotments, and used to calculate the SWAT grazing inputs that were used for all years modeled, including 2007. Grazing allotment boundaries do not match the SWAT subbasin boundaries, and in some cases extend outside the project area boundary. Therefore, the animal unit numbers for each subbasin were estimated using the proportion of the allotment area within the subbasin to the total allotment area. The estimate is also based on land use types, with specific land uses assumed grazed during each season. Partitioning the land uses and seasons for grazing calculations reflects the movement of animals to pastures and valley areas during winter months and up to forests and rangelands in the summer and fall months, according to the NRCS. This method also assumes that the grazing animals are evenly distributed in the HRUs that have grazing as a management operation. For winter and spring, only pasture land uses were included in the grazing calculations. The forest and range lands on USFS property were used for estimating summer grazing inputs. Pasture and range land use types (as either private land or USFS allotments) were used to calculate grazing inputs for fall.

A similar procedure using NRCS zones instead of USFS allotments was used to calculate the number of animal units on private land in a subbasin (Figure A-10). The NRCS zones incorporate several subbasins. The total animal units for the NRCS zone were distributed among the subbasins using the proportion of private grazeable land within a subbasin to the total private grazeable land in the NRCS zone. The same assumptions about land uses by season were used for private grazing.

Each subbasin except Rockport 8 is wholly contained within a single NRCS zone. In order to generate grazing numbers for Rockport 8, the subbasin was split into two parts, 8a and 8b. The acreage of private grazeable areas and USFS allotment area was calculated for both 8a and 8b. Since 8a only contained public grazing on a USFS allotment, public grazing animal unit numbers calculated from 8a are used directly for subbasin 8.The private grazing numbers from 8a and 8b were combined using an area-weighted average to determine the total animal units grazed on private property for the entire Rockport 8 subbasin.

The estimates of animal units for each season were used to calculate the biomass consumed (kilograms per hectare per day), biomass trampled (kg/ha/day) and manure deposited (kg/ha/day) for each season using the ratio of 10-7-5 for biomass consumed-biomass trampled-manure deposited (personal communication between Thomas Hoskins, NRCS, and Erica Gaddis, SWCA, December 12, 2013) and a starting estimate of 30 pounds per day consumed per animal unit. Grazing inputs are summarized in Table A-12.

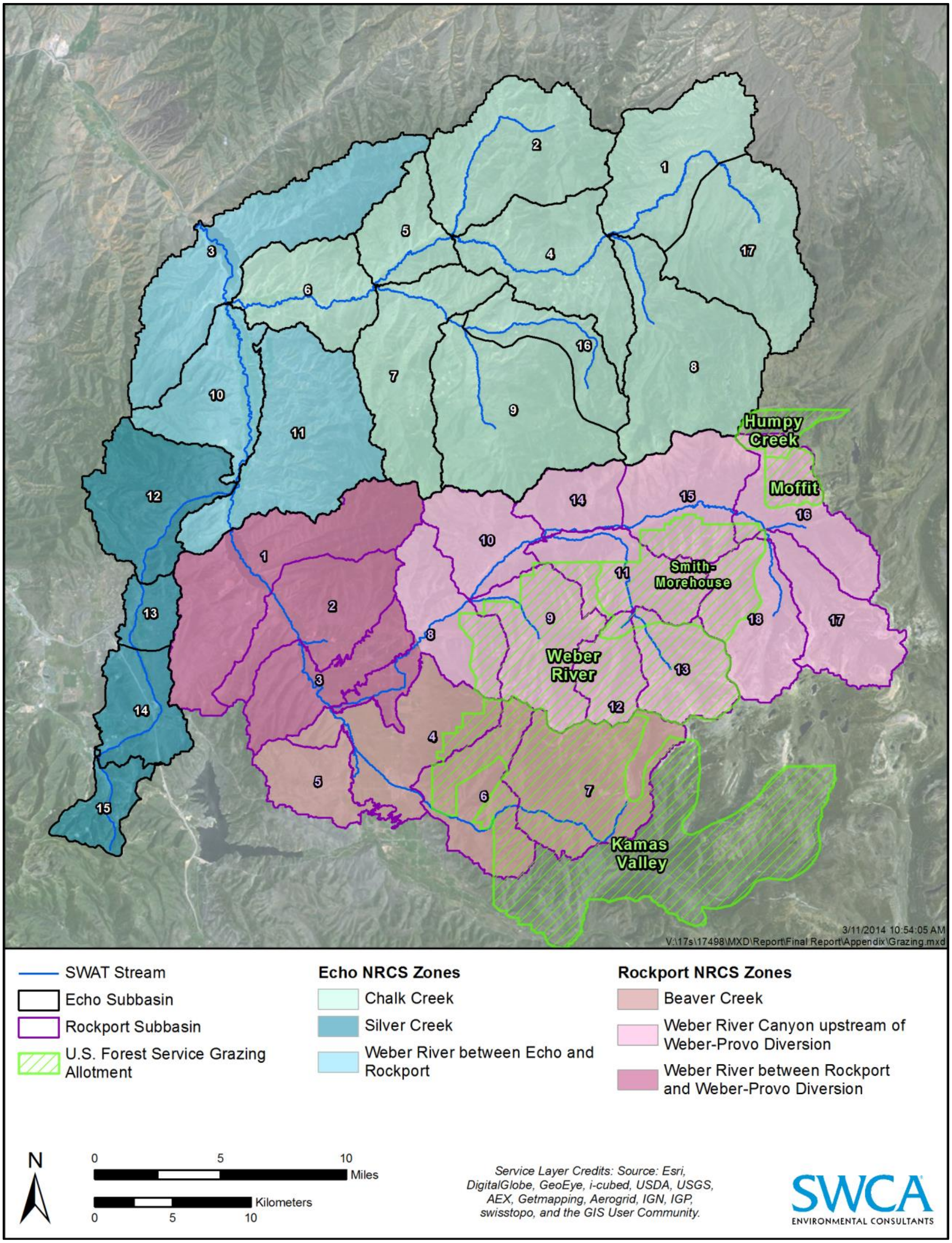

Figure A-10. Zones used to broadly quantify the number of grazing animals on private property (NRCS zones) and the locations of USFS allotments within the Rockport Reservoir and Echo Reservoir watershed.

Table A-12. Grazing Inputs Used for SWAT

Watershed and Subbasins	Allotment or NRCS Zone	Grazing Start Date/Season	Land Uses Included (if present in a subbasin) [1]	Dry Weight of biomass Consumed for Cows/Sheep (kg/ha/day)	Dry Weight of Biomass Trampled by Cows/Sheep (kg/ha/day)	Dry Weight of Manure Deposited Daily by Cows/Sheep (kg/ha/day)
Rockport Subbasins 4, 6, 7	Kamas Valley (USFS allotment)	June 10	Mixed Forest, Range	0.45/0	0.31/0	0.22/0
Rockport Subbasins 9, 12, 13, 8a	Weber River (USFS allotment)	June 21	Mixed Forest, Range	0.22/0	0.15/0	0.11/0
Rockport Subbasin 16	Humpy Creek (USFS allotment)	July 25	Mixed Forest, Range	0/3.72	2.60/0	1.80/0
Rockport Subbasin 16	Moffit Creek (USFS allotment)	July 11	FRPG, RGPG, RBPG	0/3.58	0/2.50	0/1.73
Rockport Subbasins 4, 5, 6, 7	Beaver Creek (NRCS Zone)	Winter (Dec 22–March 21)	PAST, PAS1, PAS2, PAS3	9.11/4.56	6.38/3.19	4.56/2.20
		Spring (March 22–June 21)	Pasture	9.11/4.56	6.38/3.19	4.56/2.20
		Summer (June 22–September 21)	Mixed Forest, Range	7.29/3.64	5.10/2.55	3.64/1.76
		Fall (September 22–December 21)	Range, Pasture	4.99/2.50	3.49/1.75	2.50
1.21 Rockport Subbasins (8), 9, 10, 11, 12,13, 14	Weber Canyon above the Weber-Provo Diversion (NRCS Zone)	Winter (December 22–March 21)	Pasture	(1.29/0.65) 5.89/2.95	(0.90/0.45) 4.13/2.06	(0.65/0.31) 2.95/1.42
		Spring (March 22–June 21)	Pasture	(1.71/0.86) 11.79/5.89	(1.20/0.60) 8.25/4.13	(0.86/0.41) 5.89/2.85
		Summer (June 22–September 21)	Mixed Forest, Range	(3.86/1.93) 4.96/2.48	(2.70/1.35) 3.47/1.74	(1.93/0.93) 2.48/1.20
		Fall (September 22–December 21)	Range, Pasture	(1.41/0.71) 6.13/3.06	(0.99//0.71) 4.29/2.14	(0.71/0.34) 3.06/1.48
Rockport Subbasins 1, 2, 3	Weber River between Rockport and Weber-Provo Diversion (NRCS Zone)	Winter (December 22–March 21)	Pasture	4.53/2.27	3.17/1.59	2.27/1.10
		Spring (March 22–June 21)	Pasture	4.53/2.27	3.17/1.59	2.27/1.10

Table A-12. Grazing Inputs Used for SWAT

Watershed and Subbasins	Allotment or NRCS Zone	Grazing Start Date/Season	Land Uses Included (if present in a subbasin) [1]	Dry Weight of biomass Consumed for Cows/Sheep (kg/ha/day)	Dry Weight of Biomass Trampled by Cows/Sheep (kg/ha/day)	Dry Weight of Manure Deposited Daily by Cows/Sheep (kg/ha/day)
		Summer (June 22–September 21)	Mixed Forest, Range	2.40/1.20	1.68/0.84	1.20/0.58
		Fall (September 22–December 21)	Range, Pasture	2.65/1.32	1.85/0.93	1.32/0.64
Echo Subbasins 12, 13, 14, 15	Silver Creek (NRCS Zone)	Winter (December 22–March 21)	Pasture	1.88/0.94	1.31/0.66	0.94/0.45
		Spring (March 22–June 21)	Pasture	1.88/0.94	1.31/0.66	0.94/0.45
		Summer (June 22–September 21)	Mixed Forest, Range	2.64/1.32	1.85/0.93	1.32/0.64
		Fall (September 22–December 21)	Range, Pasture	1.42/0.71	0.99/0.50	0.71/0.34
Echo Subbasins 10,11	Weber River between Rockport Reservoir and Echo Reservoir (NRCS Zone)	Winter (December 22–March 21)	Pasture	16.17/8.09	11.32/5.66	8.09/3.91
		Spring (March 22–June 21)	Pasture	2.49/1.25	1.74/0.87	1.25/0.60
		Summer (June 22–September 21)	Mixed Forest, Range	2.49/1.25	1.74/0.87	1.25/0.60
		Fall (September 22–December 21)	Range, Pasture	6.09/3.04	4.26/2.13	3.04/1.47
Echo Subbasins 1, 2, 4, 5, 6, 7, 8, 9, 16, 17	Chalk Creek (NRCS Zone)	Winter (December 22–March 21)	Pasture	5.89/2.94	4.12/2.06	2.94/1.42
		Spring (March 22–June 21)	Pasture	5.89/2.94	4.12/2.06	2.94/1.42
		Summer (June 22–September 21)	Mixed Forest, Range	1.15/0.57	0.80/0.40	0.57/0.28
		Fall (September 22–December 21)	Range, Pasture	2.37/1.18	1.66/0.83	1.18/0.57

1 FRST = forest, RNGE = grass range, RNGB = shrub range, PAST = pasture no irrigation identified, PAS1= pasture not irrigated, PAS2 = pasture sprinkler irrigated, PAS3 = pasture flood irrigated, FRPG = forest on USFS allotment (public grazing), RGPG = grass range on USFS allotment (public grazing), RBPG = brush range on USFS allotment (public grazing). If individual land uses were not present for a given subbasin, no grazing was present and no values were applied.

A-3.2.7 Agricultural Assumptions

The NRCS office in Coalville supplied information on crops grown in the Rockport Reservoir and Echo Reservoir watersheds. Three zones in each watershed were created to allow the NRCS to broadly estimate the type of crops grown in areas of each watershed. Zones in the Echo Reservoir watershed include Chalk Creek, Silver Creek, and the Weber River between Rockport Reservoir and Echo Reservoir. The Rockport Reservoir watershed is split into zones covering the Beaver Creek watershed, the Weber River Canyon Upstream of the Weber-Provo Diversion, and the Weber River between Rockport and the Weber-Provo Diversion. The NRCS submitted estimates of crop percentages in each zone and general assumptions for alfalfa crops including the planting date, rotation, and average crop yield. The NRCS assumed a general planting date of May 15. However, to make the planting date fit better with estimated dates for start of irrigation and fertilizer application, the planting date was adjusted to May 1. The NRCS estimated two cuttings per year for alfalfa, a rotation of 9 years, and an average crop yield of 2,000 kilograms. Crops were not rotated in the model; therefore, the crops assigned to each land use remain the same for the duration of the simulation.

A-3.2.8 Fertilizer Data Inputs

Fertilizer was applied to alfalfa, generic agriculture, and hay land use types and for all soil types at a uniform application rate of 35 kg/year. Fertilizer application was limited to slope classes 0–10% and 10–20%. The NRCS identified commercial fertilizer and dairy manure as the primary fertilizer types that farmers use in the watershed. A commercial fertilizer with an N:P:K ratio of 11-52-00 was applied to alfalfa and agriculture. Although the NRCS suggested a fertilizer ratio of 11-52-11, the 11-52-00 ratio was used because SWAT does not model potassium inputs. Areas identified as hay were assumed to be fertilized with 130 kg N/60 kg P based on additional discussion with NRCS personnel.

The NRCS also estimated that while about 80% of the watershed is fertilized with commercial fertilizer, 20% of the agricultural areas are fertilized with dairy manure (personal communication between Thomas Hoskins, NRCS, and Erica Gaddis, SWCA, December 12, 2012). The locations of dairies in the watershed determined which areas in a subbasin would likely use dairy manure based on the assumption that alfalfa and agriculture areas within a 1-mile radius of a dairy would likely use dairy manure for fertilizer.

Low and medium density urban land uses were assumed to use the SWAT provided fertilizer type, with an application rate of 5 kg/ha. Fertilizer was not applied to high density urban land uses.

A-3.2.9 Septic Systems

The Summit County Health Department supplied paper records with information about known septic systems in the project watershed, and the Summit County GIS department supplied additional information about septic systems in the watershed in a GIS format. The paper dataset was added to the GIS data by scanning the paper records and creating an Excel table from the scanned records. The Parcel ID was used to combine records from each dataset. The merged dataset contains information about buildings including age, size, and type of building as well as more detailed information for some records including the type of trench and building/septic location in latitude and longitude. This dataset, along with the National Hydrography Dataset (NHD), were used to determine the number of septic systems within a subbasin and the average distance from either a stream or reservoir within a subbasin. The total number of septic systems is used to calculate the density of septic systems in the HRU.

The septics dataset with additional input from the Summit County Health Department (personal communication, telephone call between Brent Ovard and Bob Swensen, Summit County Health

Department, and Erica Gaddis, SWCA, November 2012) was used to create three groups of septic systems: Primary, Secondary, and Recreational. The Primary category contains buildings known to be primary residences and other buildings that are likely operating all year. Buildings listed as other or unknown, including those identified as Farmland Assessment Act (FAA) buildings were included in the Primary category to maintain a conservative estimate of septic systems and their operations within the watershed. If the county data categorized a building as a secondary residence (defined as occupied six months or less), it was classified as Secondary residential for SWAT. Buildings that the county considers recreational have less than three months of occupancy over the year. Septic systems associated with recreational buildings are also categorized as Recreational septic systems in the SWAT septic tables (Figure A-11).

Nutrient loads from Primary, Secondary, and Recreational septic systems were assumed proportional to the estimated amount of time a residence is occupied. The default values for a conventional drain field were used for primary residences. For Secondary and Recreational septic systems, new SWAT categories with unique four-digit codes were created that contain the default nutrient concentrations but proportionally reduced discharges (Table A-13). The discharge values were reduced by the proportion of the year the septic system is assumed active to reduce the annual nutrient loads from septic systems. Secondary residences are assumed occupied for 6 months, therefore the load inputs are 50% of the default values. Recreational residences load inputs are 25% of the default values since these buildings are assumed occupied for only 3 months per year. This approach only reduces the annual load for Secondary and Recreational inputs because SWAT runs on a daily timestep. Therefore, SWAT models these septic systems as contributing on a daily basis; the loads are just reduced. The approach does not account for an increase or decrease of septic system inputs based on when the septic systems are active and/or on a seasonal basis.

Table A-13. Input Values for SWAT to Model Septic System Loads

Parameter	Primary Residence	Secondary Residence	Recreational Use
Septic tank effluent flow rate m^3/capita/day	0.227	0.1135	0.05675
Seven-day biological oxygen demand mg/L	170	170	170
Total suspended solids in septic effluent mg/L	75	75	75
Total nitrogen in septic effluent mg/L	72	72	72
Ammonia in septic effluent mg/L	58	58	58
Nitrate in septic effluent mg/L	0.2	0.2	0.2
Nitrite in septic effluent mg/L	0	0	0
Organic N in septic effluent mg/L	14	14	14
Total phosphorus in septic effluent mg/L	12	12	12
Phosphate in septic effluent mg/L	10	10	10
Organic P in septic effluent mg/L	2	2	2
Fecal coliform in septic effluent cfu/100mL	10,000,000	10,000,000	10,000,000

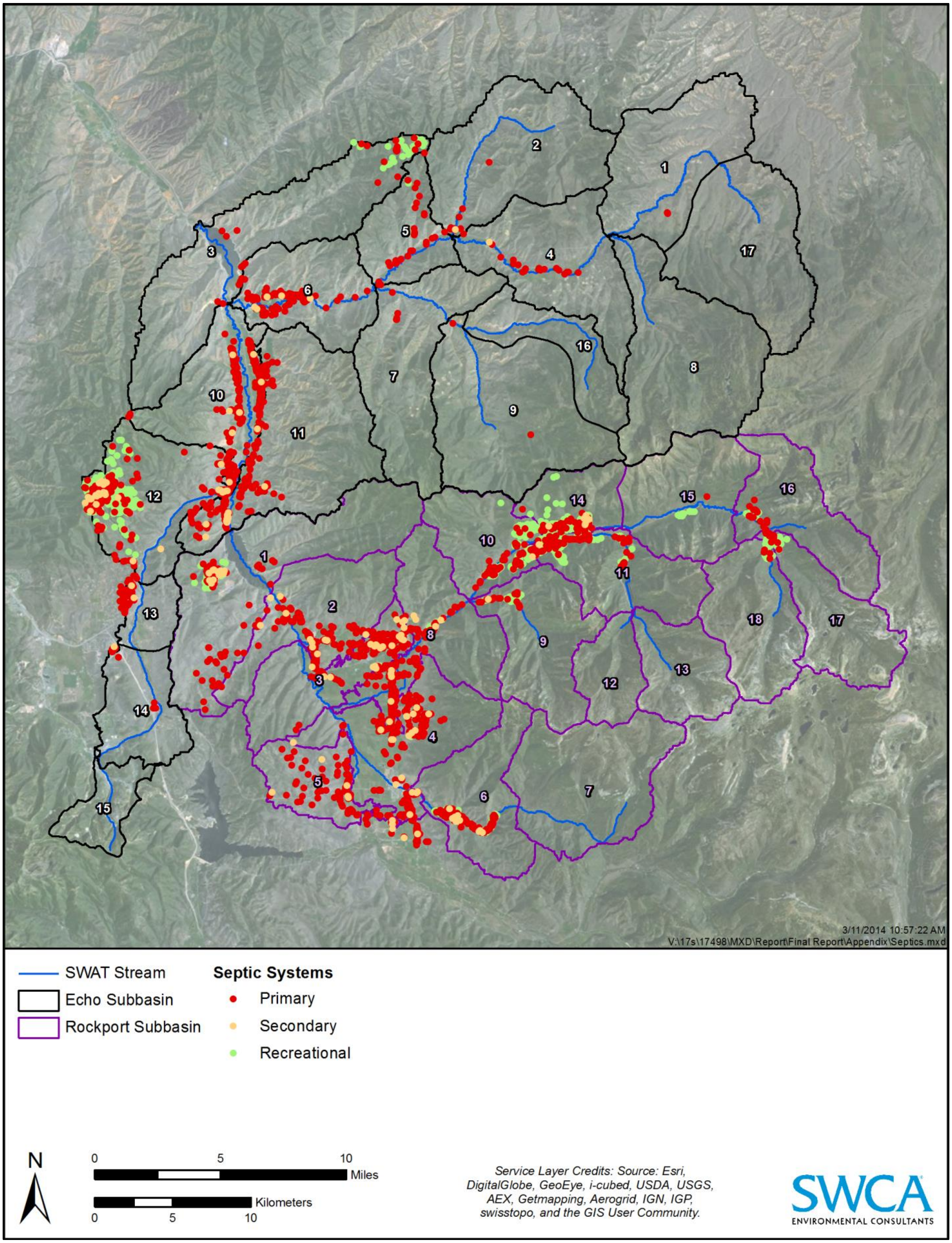

Figure A-11. Known septic systems in the Rockport Reservoir and Echo Reservoir watersheds.

SWAT will model a septic system as a hydraulic failure where septic effluent is discharged onto the ground surface and any runoff reaching a waterbody is essentially untreated. SWAT models functioning septic systems by infiltrating the effluent through the soil layers and allowing the soil to uptake and transform nutrients (Arnold et al. 2011). This difference allows for differentiation of loads from functional septic systems and failing septic systems. No data documenting the number or location of failing septic systems in the watershed were available for the project area. No data documenting the number or location of failing septic systems in the watershed were available for the project area. From discussions with the Summit County Health Department and results from bacteria and human bacteroides sampling that occurred in late 2012, an EPA-recommended septic system failure rate of 10% was used (EPA 2000).

SWAT does not allow an HRU to have both functional and failing septic systems, so identifying 10% of the total number of septic systems in each HRU was not feasible. Instead, 10% of septic systems were designated as failing by randomly selecting 10% of the total number of septic systems (including Primary, Secondary, and Recreational) over the entire watershed and creating HRUS with failing septic systems as a land use.

The SWAT model allows the septic system to fail for up to 10,000 days. Septic systems designated as failing were allowed to fail continuously for 6,000 days to cover the entire model time period between 1998 and 2012.

A-3.2.9.1 URBAN LAND USE HYDROLOGY

SWAT applies the USGS urban regression equations to model stormwater runoff from urban land uses. The USGS developed these equations for ungaged urban watersheds using a national urban water quality database described in the model documentation (Arnold et al. 2011). The SWAT variables adjusted for the Rockport Reservoir and Echo Reservoir watersheds include the fraction of total area that is impervious and the percent of the impervious surface area that has a direct hydrologic connection, for example, a stormwater outfall that discharges to a stream. These values were adjusted for the I-80 and US40 corridors runoff from the road surfaces will drain to grassy swales that are adjacent to the road shoulder. The values were also adjusted for other urban land use categories to reflect the existing conditions in the Rockport Reservoir and Echo Reservoir watersheds. Table A-14 shows the values used in the SWAT model by urban land use type.

Table A-14. Urban Land Use SWAT parameters

Urban Land Use Category	Land Use Code	Percent Impervious Surface (FIMP)	Percent Impervious Surface With Direct Hydrologic Connection (FCIMP)	Curb density (CURBDEN)
Urban	URBN	0.2	0.025	0.20
Urban Residential High Density	URHD	0.44	0.11	0.24
Urban Residential Medium Density	URMD	0.23	0.07	0.24
Urban Residential Medium-Low Density	URML	0.14	0.06	0.24
Urban Residential Low Density	URLD	0.07	0.015	0.16
Urban Park	PARK	0.07	0.03	0.24
Interstate 80 Corridor	I80	0.7	0.2	0.12
US Highway 40 Corridor	US40	0.07	0.2	0.12

A-3.2.10 Point Source Inputs

Point sources of pollution are characterized by specific points of discharge (e.g. pipes) that convey wastewater into a waterbody. Point sources are regulated under Utah Pollutant Discharge Elimination System (UPDES) permitting program. In the Rockport Reservoir watershed, point sources include the Kamas City WWTP, Oakley City WWTP, and the UDWR Fish Hatchery near Kamas. The UDWR hatchery is only used in scenarios to develop a load allocation for future operations. The hatchery was offline much of the time period used for the SWAT model. The Silver Creek Water Reclamation Facility (WRF); the Park City drains, which include Judge Tunnel, the Spiro Tunnel, the Prospector Drain and the Biocell; and the Coalville WWTP are treated as point sources in the Echo Reservoir watershed (Figure A-12). Because SWAT allows only one point source per subbasin, the Judge Tunnel, Spiro Tunnel, Prospector Drain, and Biocell discharges were combined into a single point source for the SWAT model.

All point source files were generated using monthly data. SWAT inputs include the mineral and organic fractions of phosphorus and nitrogen, with nitrogen further partitioned into ammonia, nitrite, and nitrate. For all WWTPs, the 30-day average or monthly average value for each calendar month was based on available data from 2002 – 2012. If the required data were not available, specific assumptions were made for each wastewater treatment plant in order to complete the SWAT input files. If a blank record existed between two months with values, the blank record was populated with an average of the two adjacent values. There were no available data from the Oakley, Kamas, and UDWR hatchery sources for several parameters. SWCA worked closely with UDEQ to develop appropriate assumptions for those treatment plants that are discussed in individual sections below.

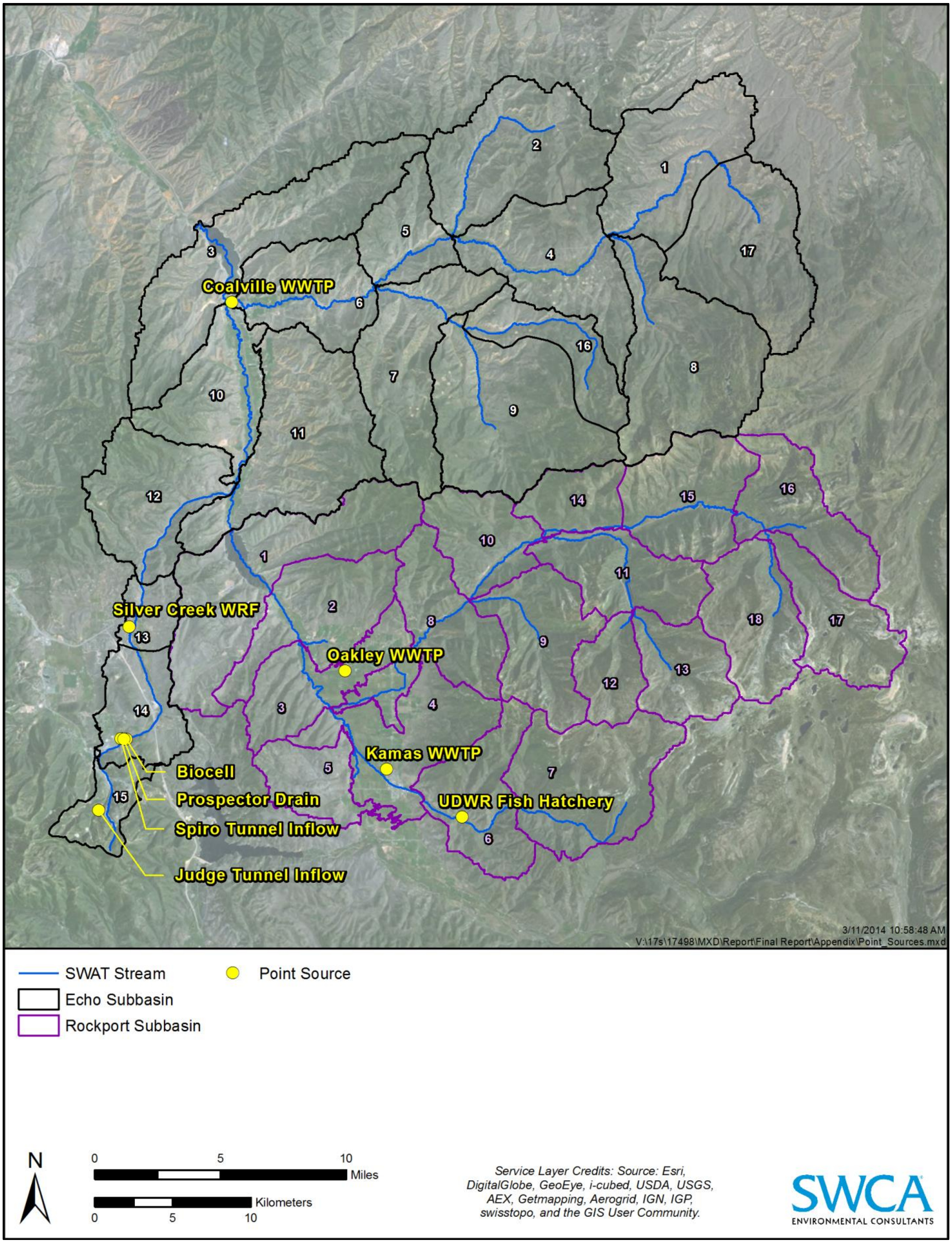

Figure A-12. Location of current point source discharges in the Rockport Reservoir and Echo Reservoir watersheds.

A-3.2.10.1 KAMAS CITY WASTEWATER TREATMENT PLANT

The Kamas City Wastewater Treatment Plant (UPDES UT0020966) serves a population of approximately 1,500 people. The Kamas plant was most recently upgraded in 1991. Current design includes an 18-inch inlet pipe leading to five waste stabilization ponds, the first three of which are aerated with seven 20-horsepower aerators. Effluent is treated with ultraviolet light disinfection. The five lagoons cover approximately 18.8 acres. The plant was designed for average daily flows of 1.0 million gallons per day (MGD) and recent analysis suggests it can treat 1,750 pounds of biological oxygen demand (BOD) per day.

Several assumptions were made to develop SWAT inputs that characterize the effluent from the Kamas City WWTP for the model. Total phosphorus concentration was assumed to be 3.5 mg/L with a negligible organic component. A total nitrogen concentration of 16 mg/L was assumed, 30% of which was assumed to be organic. These values were based on effluent data from other lagoon systems in Utah that are located in a similar climate and have a similar retention time and were provided by Paul Krauth of UDEQ. The system found to be most similar to the Kamas system is the Midway lagoon system. Total suspended solids and BOD inputs were based on average monthly data specific to each year. The loads for 2007 are summarized in Table A-15.

Table A-15. Average Monthly SWAT Point Source Inputs for the Kamas City WWTP

Month	Flow (m^3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Jan	238.48	0.002	1.15	0.0	2.00	0.67	0.0	0.84	1.55
Feb	302.83	0.005	1.45	0.0	2.54	0.85	0.0	1.06	7.87
Mar	359.61	0.006	1.73	0.0	3.02	1.01	0.0	1.26	5.39
Apr	416.40	0.017	2.00	0.0	3.50	1.17	0.0	1.46	8.33
May	776.01	0.017	3.723	0.0	6.52	2.17	0.0	2.72	13.46
Jun	1,135.62	0.006	5.45	0.0	9.54	3.18	0.0	3.98	1.14
Jul	454.25	0.002	2.18	0.0	3.82	1.27	0.0	1.59	0.23
Aug	264.98	0.001	1.27	0.0	2.23	0.74	0.0	0.93	0.13
Sep	208.20	0.001	1.00	0.0	1.75	0.58	0.0	0.73	2.52
Oct	227.12	0.001	1.09	0.0	1.91	0.67	0.0	0.80	1.36
Nov	283.91	0.001	1.36	0.0	2.39	0.80	0.0	0.99	0.28
Dec	293.37	0.002	1.41	0.0	2.46	0.82	0.0	1.03	1.91

A-3.2.10.2 OAKLEY CITY WASTEWATER TREATMENT PLANT

The Oakley City Wastewater Plant (UPDES UT0020061) was designed for daily flows of 0.25 mgd. The plant treatment train includes a 2-mm screen and compactor, grit removal, aeration basin and a membrane bioreactor for microfiltration. Waste is treated with an ultraviolet disinfection system before being discharged into the Weber River.

The membrane bio-reactor effectively removes all solids from the effluent. Thus, the TSS concentration was assumed to be 0, as reported on monthly DMR reports. Phosphorus data available for Oakley City WWTP consists of daily maximum values and could not be used to estimate an average monthly value.

An average total phosphorus concentration of 1.5 mg/L was assumed for the Oakley City WWTP, which represents a conservative monthly average for the type of treatment system used in Oakley. All of the phosphorus was assumed to be mineral. Nitrogen data were not available and the only BOD data available for the Oakley City WWTP was from 2001 to 2003, which does not reflect the effluent characteristics of the recently upgraded facility. The total nitrogen concentration in the Oakley effluent was assumed to be 10 mg/L, 30% of which was assumed to be organic. BOD was assumed to be 4 mg/L. These values (Table A-16) were based on design effluent for the upgraded Oakley City WWTP and provided by Paul Krauth of UDEQ and confirmed with Bob Johnson of Oakley on December 7, 2012.

Table A-16. Average Monthly SWAT Point Source Inputs for the Oakley City WWTP

Month	Flow (m3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Jan	427.75	0	1.28	0	2.25	0.75	0	0.64	1.71
Feb	3,217.60	0	9.65	0	16.89	5.63	0	4.83	12.9
Mar	416.40	0	1.25	0	2.19	0.73	0	0.63	1.67
Apr	658.66	0	1.98	0	3.46	1.15	0	0.99	2.64
May	586.74	0	1.76	0	3.08	1.03	0	0.88	2.35
Jun	541.31	0	1.62	0	2.84	0.95	0	0.81	2.17
Jul	427.75	0	1.28	0	2.25	0.75	0	0.64	1.71
Aug	416.4	0	1.25	0	2.19	0.73	0	0.63	1.67
Sep	707.87	0	2.12	0	3.72	1.24	0	1.06	2.83
Oct	2,876.91	0	8.63	0	15.10	5.04	0	4.32	11.51
Nov	3,520.428	0	10.561	0	18.482	6.161	0	5.281	14.082
Dec	2,937.134	0	8.811	0	15.42	5.14	0	4.406	11.749

A-3.2.10.3 UDWR FISH HATCHERY NEAR KAMAS

Monthly total phosphorus and flow data for the UDWR Fish Hatchery were used directly in the SWAT input file for this point source, with some data gaps. No total nitrogen data were available for this source. As a conservative assumption, total nitrogen was assumed to be 16 mg/L (same as the Kamas City WWTP) with the same organic fractions as those assumed for Kamas. However, because the hatchery was in operation intermittently during the past 10 years and not in 2007 (the baseline model year), this point source will only be used for future scenarios and load allocations and for baseline model development.

A-3.2.10.4 COALVILLE CITY WASTEWATER TREATMENT PLANT

The Coalville City Wastewater Plant (UPDES UT0021288) serves a population of approximately 1,470 people. It was originally designed as a trickling filter plant in 1964. Since then, three upgrades have been completed. First, in 1985, the plant was modified to an extended aeration/activated sludge plant. Subsequent additions include two biosolids drying beds in 1992, and the addition of a Somat screw press for dewatering, a composting pad, and alterations to existing drying beds in 1995. Plant design allows for an average daily flow of 0.35 MGD and peak flow of 0.42.

Average monthly DMR data and additional data provided by JUB, consulting engineer to Coalville City, were used to develop inputs for SWAT (Table A-17). Although historic data is used to calibrate the watershed model, design values for the new wastewater treatment plant were used for scenario analyses.

Table A-17. Average Monthly Point Source Inputs for the Coalville City WWTP

Month	Flow (m3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Jan	738.15	0.003	0.23	0.0	4.04	0.369	0.021	0.54	0.74
Feb	757.08	0.003	0.50	0.0	4.45	0.303	0.018	0.53	3.79
Mar	632.16	0.002	0.19	0.0	3.68	2.529	0.015	0.23	0.63
Apr	654.88	0.003	0.56	0.0	3.26	0.262	0.033	2.82[1]	0.66
May	825.22	0.003	0.17	0.0	4.52	0.330	0.041	0.30	2.48
Jun	870.64	0.004	0.67	0.0	5.03	0.348	0.044	0.37	4.35
Jul	776.01	0.003	1.12	0.0	4.25	0.310	0.039	0.27	0.78
Aug	859.29	0.003	0.32	0.0	3.61	0.344	0.043	1.26	2.58
Sep	942.57	0.004	0.46	0.0	4.83	0.377	0.047	1.36	2.83
Oct	870.64	0.005	0.65	0.0	5.29	0.348	0.026	1.48	2.61
Nov	741.94	0.004	1.38	0.0	4.42	0.297	0.022	0.72	2.27
Dec	723.01	0.003	0.32	0.0	3.92	0.289	0.013	0.48	2.89

[1] Includes a high value of 7.4 mg/L form April 2011.

A-3.2.10.5 SILVER CREEK WATER RECLAMATION FACILITY

The Snyderville Basin Water Reclamation District operates the Silver Creek WRF (UPDES UT0024414), a conventional, secondary treatment plant that services residential areas and permitted Significant Industrial Users in portions of the watershed, including areas of Park City. Constituents with specific effluent limitations are DO, BOD, total suspended solids, ammonia, *E. coli*, oil and grease, and pH (Snyderville Basin Water Reclamation District 2013). Phosphorus is not regulated with a specific effluent limitation, but is sampled on a monthly basis under the existing permit, which is currently in the process of being renewed. No flow limit is indicated in the UPDES permit, but the current facility has a capacity of 2.0 MGDMGD. An average monthly flow is approximately 2 cubic feet per second (cfs), or 1.3 mgd. Upgrades are currently being planned, with final designs based on a discharge of 4.0 MGD. The designs and technology included in the upgrades depend on the effluent concentrations identified in the UPDES permit. DMR data and supplemental data provided by the Snyderville Basin Water Reclamation District were used to develop average monthly inputs for SWAT (Table A-18).

Table A-18. Average monthly SWAT point source inputs for the Silver Creek WRF

Month	Flow (M3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Jan	4,455.42	0.027	6.85	0.0	82.74	0.45	0.84	14.04	17.82
Feb	4,913.46	0.025	5.85	0.0	90.88	0.98	0.92	17.20	19.65
Mar	6,900.80	0.028	10.78	0.0	126.07	1.38	1.27	17.48	20.70

Table A-18. Average monthly SWAT point source inputs for the Silver Creek WRF

Month	Flow (M3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Apr	4,762.04	0.019	3.75	0.0	57.78	1.91	0.58	5.40	23.81
May	4,213.16	0.025	6.17	0.0	51.18	0.84	0.52	5.76	16.85
Jun	3,951.96	0.016	4.63	0.0	87.61	0.40	0.89	7.91	19.76
Jul	4,379.72	0.018	4.11	0.0	81.04	0.88	0.82	12.59	13.14
Aug	4,580.34	0.032	8.00	0.0	90.46	1.37	0.91	12.83	22.90
Sep	3,550.71	0.014	3.88	0.0	67.92	0.36	0.69	9.01	10.65
Oct	4,182.87	0.025	5.22	0.0	76.69	0.84	0.78	10.77	25.10
Nov	4,186.66	0.020	5.22	0.0	74.53	1.26	0.75	12.98	20.93
Dec	4,890.75	0.038	8.71	0.0	81.51	4.40	0.82	15.75	34.24

A-3.2.10.6 JUDGE TUNNEL

Judge Tunnel carries groundwater from a series of mine tunnels to a chlorination vault where the flow is treated and becomes drinking water for Park City (Figures A-12 and A-13). If the turbidity is too high (approximately 1–2 nephelometric turbidity units[NTUs]), the water bypasses the vault and is released into Empire Creek, a tributary to Silver Creek (personal communication between Kyle MacArthur, Park City Municipal Corporation and Erica Gaddis, SWCA, December 19, 2012). Judge Tunnel's average monthly flow is somewhat variable with increased discharges during months with increased precipitation, but generally small compared to mainstem flows. The average monthly discharge is 0.4 cfs. The data used were compiled primarily from monitoring data provided by UDEQ and Park City Municipal Corporation. This included monthly flows from 2004 to 2011. Gaps in this dataset were populated by average monthly values. Little water quality data existed for the Judge Tunnels, so four samples from 2010 and 2011 were averaged for TSS, nitrate, and total phosphorus, while two samples from 2010 were averaged for BOD (site JT-9). Organic nitrogen and ammonia concentrations were estimated using data from Spiro Tunnel (Park City monitoring sites ST-23, ST- 24, and ST-26) because no data were available for Judge Tunnel (Table A-19).

Table A-19. SWAT point source inputs for the Judge Tunnel for model year 2007

Month	Flow (m^3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Jan	1,118.17	0.003	0.335	0.0	0.145	0.112	0.0	0.045	2.80
Feb	1,470.64	0.004	0.441	0.0	0.191	0.147	0.0	0.059	3.68
Mar	1,364.95	0.004	0.409	0.0	0.177	0.136	0.0	0.055	3.41
Apr	1,907.35	0.005	0.572	0.0	0.248	0.191	0.0	0.076	4.77
May	3,361.95	0.009	1.009	0.0	0.437	0.336	0.0	0.134	8.41
Jun	109.78	0.000	0.033	0.0	0.014	0.011	0.0	0.004	0.27
Jul	41.76	0.000	0.013	0.0	0.005	0.004	0.0	0.002	0.10
Aug	63.74	0.000	0.019	0.0	0.008	0.006	0.0	0.003	0.16

Table A-19. SWAT point source inputs for the Judge Tunnel for model year 2007

Month	Flow (m^3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Sep	14.01	0.000	0.004	0.0	0.002	0.001	0.0	0.001	0.04
Oct	239.95	0.001	0.072	0.0	0.031	0.024	0.0	0.010	0.60
Nov	1,213.23	0.003	0.364	0.0	0.158	0.121	0.0	0.049	3.03
Dec	466.58	0.001	0.140	0.0	0.061	0.047	0.0	0.019	1.17

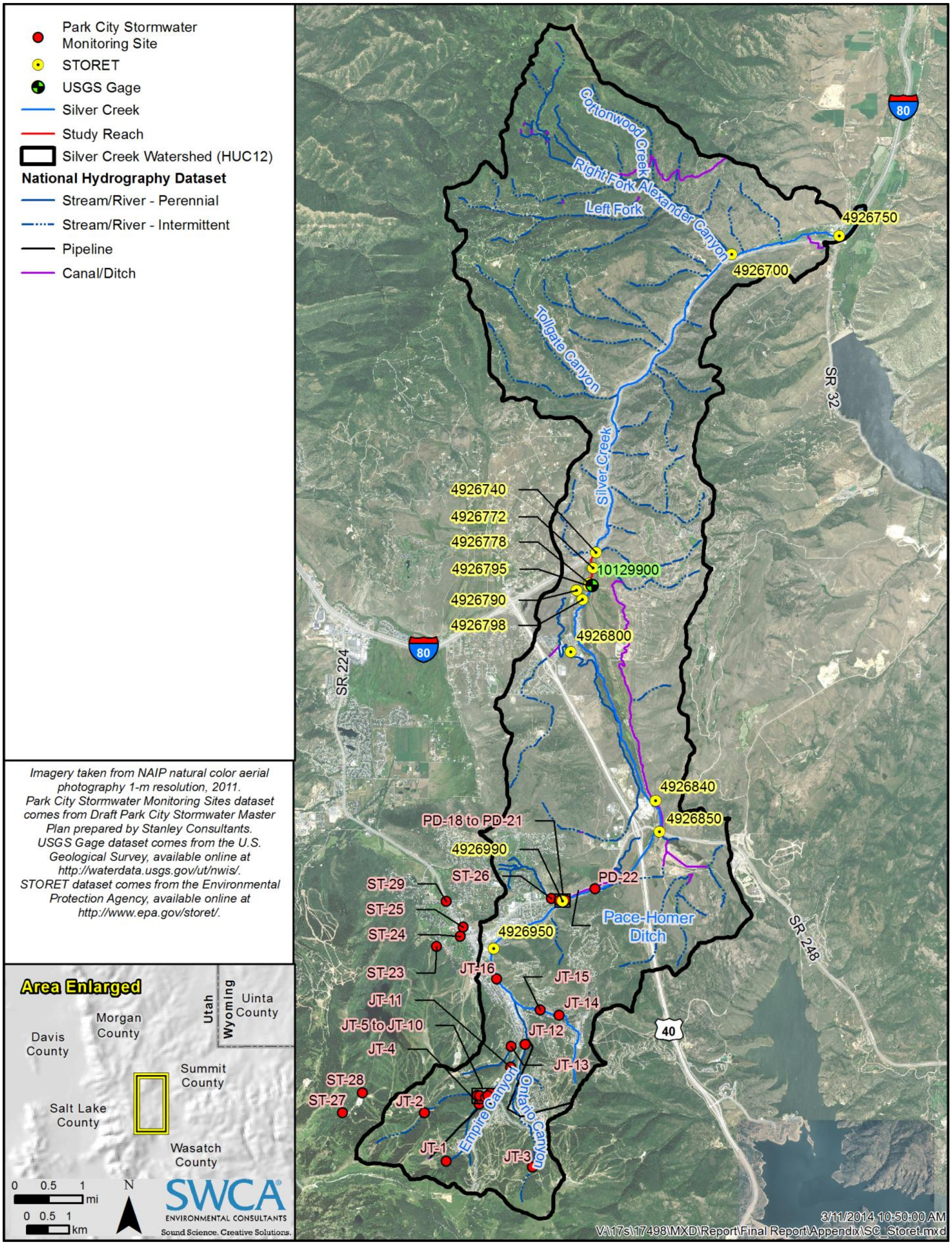

Figure A-13. Location of tunnels and Park City monitoring sites used to estimate flows and loads.

A-3.2.10.7 SPIRO TUNNEL

Like Judge Tunnel, Spiro Tunnel collects groundwater from mine tunnels (Figure A-13). Spiro Tunnel discharges water into two irrigation ditches in the Silver Creek watershed: the Bates, Snyder, Dority Ditch and the Pace Homer Ditch. Spiro Tunnel discharges directly into Silver Creek at the Pace Homer Ditch (Park City Municipal Corporation 2012). Spiro Tunnel average discharge is approximately 1.5 cfs.

At location ST-25, the pipe splits flow into the Bates, Snyder, Dority Ditch, which takes flow to the Silver Creek drainage. There is also a diversion approximately 750 feet east and downstream of ST-29, which carries water into the Silver Creek drainage. The two diversions comingle before reaching ST-26. At ST-26, spring water and stormwater has mixed in with the mine drainage, at which point it becomes the Pace Homer Ditch. This site is the direct discharge into Silver Creek. Flow measurements taken at the ST-23 site and the ST-30 were used to characterize inflow to Silver Creek from Spiro Tunnel only. Both sites are needed because flow is partitioned between Silver Creek and East Canyon at ST-25 (personal communication between Joan Card, Park City Corporation, and Erica Gaddis, SWCA on December 19, 2012).

The data used were compiled from monitoring data provided by UDEQ and Park City Municipal Corporation. Average data for the following parameters from site ST-23 were used to characterize the water quality of flow to Silver Creek that originates from Spiro Tunnel: Ammonia as Nitrogen, Biological Oxygen Demand, Nitrate, Nitrite, Phosphorus, Orthophosphate, Total Kjeldahl Nitrogen, and Total Suspended Solids. Organic nitrogen was calculated as TKN minus ammonia for an average value of 0.3 mg/L.

Flow values for Spiro Tunnel were provided by Park City. This included monthly flows from 2004 to 2011. Gaps in this dataset were populated by average monthly values. Water quality values for Spiro Tunnel were averaged based on available samples (Table A-20).

Table A-20. 2007 SWAT Point Source Inputs for the Spiro Tunnel

Month	Flow (m3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic Phosphorus (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
Jan	72.26	0.000	0.022	0.0	0.009	0.007	0.0	0.001	0.18
Feb	315.43	0.001	0.095	0.0	0.038	0.032	0.0	0.006	0.79
Mar	285.14	0.001	0.086	0.0	0.034	0.029	0.0	0.006	0.71
Apr	97.46	0.000	0.029	0.0	0.012	0.010	0.0	0.002	0.24
May	8004.71	0.017	2.401	0.0	0.961	0.800	0.0	0.160	20.01
Jun	7490.40	0.016	2.247	0.0	0.899	0.749	0.0	0.150	18.73
Jul	7396.61	0.016	2.219	0.0	0.888	0.740	0.0	0.148	18.49
Aug	9538.87	0.020	2.862	0.0	1.145	0.954	0.0	0.191	23.85
Sep	6362.60	0.013	1.909	0.0	0.764	0.636	0.0	0.127	15.91
Oct	2971.78	0.006	0.892	0.0	0.357	0.297	0.0	0.059	7.43
Nov	537.72	0.001	0.161	0.0	0.065	0.054	0.0	0.011	1.34
Dec	304.11	0.001	0.091	0.0	0.036	0.030	0.0	0.006	0.76

A-3.2.10.8 PROSPECTOR DRAIN AND BIOCELL

Prospector Drain collects shallow groundwater impacted by mine tailings. This drain also collected stormwater until 2012 when Park City eliminated cross-connections from stormwater sources.

A portion of flow from Prospector Drain goes into the Biocell, which treats the water for metal contamination. The Biocell contains organic matter in the form of manure, which may explain the high nutrient concentrations in the Biocell discharge, which goes to Silver Creek. The remaining water in Prospector Drain flows untreated to Silver Creek (Park City Municipal Corporation 2012). These sources contribute a relatively small quantity of flow to Silver Creek. The Prospector Drain discharges an estimated 0.07 cfs (site PD-18), of which approximately half (0.036 cfs) is routed through the Biocell (Site PD-19) (see Figure A-13).

The Biocell and Prospector Drain are expected to be part of an Environmental Protection Act (EPA)–directed *Comprehensive Environmental Response, Compensation, and Liability Act* removal action in the foreseeable future. The discharges from these sources will be addressed pending EPA approval of a removal action. Therefore, no UPDES permit will be issued for these point sources until the EPA-directed removal action is complete (Park City Municipal Corporation 2012).

The data used were compiled primarily from data provided by the UDEQ and Park City Municipal Corporation. Water quality values for Prospector Drain and Biocell were averaged from available data or assumed to be zero. However, Prospector Drain and Biocell data were combined as weight-based averages for inputs into SWAT (Table A-21).

Table A-21. Combined SWAT Point Source Inputs for the Prospector Drain and Biocell

Flow (m^3/day)	TSS (metric tons/day)	Organic Nitrogen (kg/day)	Organic P (kg/day)	Nitrate (kg/day)	Ammonia (kg/day)	Nitrite (kg/day)	Mineral P (kg/day)	BOD (kg/day)
265	0.002	0.09	0.0	0.54	0.03	0.0	0.2	1.3

A-3.2.10.9 COMBINED POINT SOURCES IN SWAT

SWAT allows the user to place a single point source in each subbasin. Therefore, the values generated for Judge Tunnel, Spiro Tunnel, Prospector Drain, and the Biocell were added together and a single file was created for SWAT. For wastewater treatment plants with multiple discharge locations, the flow and loads for individual discharge points were added to estimate a total flow and load discharged from the facility.

A-3.2.11 Hydrologic Parameters

A-3.2.12 Snow and Evapotranspiration Parameters

SWAT users can assign evapotranspiration parameters and snow parameters for the watershed or at the subbasin level. This allows better simulation of snow-melt dominated watersheds, where changes in elevation affect precipitation and temperature, thereby affecting the hydrology. Evapotranspiration parameters are used to adjust how SWAT meets evaporative demand from the soil and how deep in the soil plants are allowed to obtain water. For this model, the Penman-Montieth equation was chosen to estimate potential evapotranspiration. Snow parameters include the threshold temperature at which snow melts and whether precipitation occurs either as rain or snow. The adjusted snow parameters and the values used for all subbasins are shown in Table A-22.

Table A-22. Watershed Level Snow and Evapotranspiration Parameters used in the SWAT Model

Parameter Name	Parameter Description	Final Value used for Rockport	Final Value used for Echo
ESCO	Soil evaporation compensation factor	0.95	0.8
EPCO	Plant uptake compensation factor	1.0	1.0
SNOCOVMX	Areal snow coverage threshold (cov100)	500	100
SNO50COV	Areal snow coverage threshold (cov50)	0.7	0.1

Subbasins can be split into elevation bands, allowing SWAT to adjust some snow parameters based on elevation within a subbasin (Table A-23). Elevations bands are topographic intervals that cover a 350 m elevation range. The base of the lowest band equals the minimum elevation for a subbasin. Segments are added until the maximum elevation is reached. Because the final elevation band may not cover exactly 350 m, the maximum elevation of the subbasin becomes the upper bound.

SWAT uses the midpoint elevation for each elevation band and it is calculated as the average of the upper and lower elevation limit. The percent of the subbasin area within each elevation band is determined using the topographic report that SWAT generates after completing the initial subbasin delineation. Elevation bands were created in both Rockport Reservoir and Echo Reservoir watersheds to account for these effects and better simulate the snow-melt dominant hydrology present in the Rockport Reservoir and Echo Reservoir watersheds.

Snow parameters adjusted by elevation band for specific subbasins are shown in Table A-24. The precipitation lapse rate adjusts the amount of precipitation as elevation increases. The temperature lapse rate decreases temperature as elevation increases. The snowfall temperature is the point at which precipitation turns to snowfall. The maximum melt coefficient is the amount of snowmelt on June 21 while the minimum snowmelt coefficient is the amount of snowmelt that occurs on December 21. The snowpack temperature lag factor affects how the snow melts while the snowpack temperature melt threshold determines at what temperature melt begins.

Table A-23. Elevation Bands Used for the SWAT Model

Subbasin	Zone 1 Mid Elevation (m)	Zone 2 Mid Elevation (m)	Zone 3 Mid Elevation (m)	% of Subbasin Area in Zone 1	% of Subbasin Area in Zone 2	% of Subbasin Area in Zone 3
Rockport Reservoir Watershed						
1	2,015	2,365	2,698	76.1%	16.8%	7.1%
2	2,017	2,367	2,615.5	69.9%	28.5%	1.6%
3	2,051	2,325.5	0	83.2%	16.8%	0.0%
4	2,088	2,438	2,864	73.2%	17.3%	9.5%
5	2,097	2,348.5	0	93.8%	6.2%	0.0%
6	2,172	2,522	2,906	45.1%	43.3%	11.6%
7	2,321	2,671	3,085	33.8%	34.1%	32.1%
8	2,088	2,438	2,864.5	44.1%	41.3%	14.6%

Table A-23. Elevation Bands Used for the SWAT Model

Subbasin	Zone 1 Mid Elevation (m)	Zone 2 Mid Elevation (m)	Zone 3 Mid Elevation (m)	% of Subbasin Area in Zone 1	% of Subbasin Area in Zone 2	% of Subbasin Area in Zone 3
9	2,235	2,585	2,997.5	18.9%	39.6%	41.5%
10	2,235	2,585	2,809	70.2%	28.8%	0.9%
11	2,320	2,670	3,034	33.6%	35.1%	31.4%
12	2,526	2,876	3,149.5	20.2%	69.4%	10.4%
13	2,525	2,875	3,257.5	15.2%	48.4%	36.4%
14	2,333	2,683	3,021.5	45.2%	46.5%	8.3%
15	2,430	2,780	3,134	35.8%	44.5%	19.8%
16	2,537	2,887	3,259.5	23.5%	50.9%	25.6%
17	2,572	2,922	3,340	17.2%	34.8%	48.0%
18	2,583	2,933	3,310.5	16.4%	55.4%	28.2%
Echo Reservoir Watershed						
1	2,218	2,568	2,773.5	88.4%	11.4%	0.2%
2	2,040	2,390	2,684.5	57.0%	40.3%	2.8%
3	1,859	2,209	2,583	55.9%	41.8%	2.3%
4	2,040	2,390	2,622.5	67.4%	31.8%	0.7%
5	1,971	2,280	2,281	65.9%	34.1%	0.0%
6	1,868	2,215.5	2,216	75.9%	24.2%	0.0%
7	1,971	2,321	2,677	47.1%	39.9%	13.0%
8	2,220	2,570	3,030	21.3%	38.2%	40.5%
9	2,049	2,399	2,879.5	35.4%	48.6%	16.0%
10	1,868	2,218	2,610	71.1%	19.4%	9.5%
11	1,915	2,265	2,579	50.0%	44.6%	5.4%
12	1,951	2,301	2,652	46.7%	44.8%	8.6%
13	2,144.5	2,568	2,773.5	100.0%	0.0%	0.0%
14	2,150	2,332	2,332	100.0%	0.0%	0.0%
15	2,251	2,601	2,911	46.8%	47.0%	6.3%
16	2,066	2,416	2,864	47.8%	29.2%	23.0%
17	2,324	2,674	2,976.5	64.7%	29.3%	6.0%

Table A-24. Subbasin Specific Snow Parameter Values (unitless constants)

Subbasin	Precipitation lapse rate (PLAPS)	Temperature lapse rate (TLAPS)	Snowfall temperature (SFTMP)	Maximum melt coefficient (SMFMX)	Minimum melt coefficient (SMFMN)	Snowpack temperature lag factor (TIMP)	Snowpack temperature melt threshold (SMTMP)
Rockport 1-7 (Beaver Creek and Inflow subbasins)	300	-6.5	1	6.5	4	0.5	1
Rockport 8-18 (Mainstem Weber River)	300	-6.5	1	8/7/6[1]	4/3/2	0.5	1
Echo 7,8,9,16,17 (Upper Chalk Creek)	100	-6.5	1	8/7/6	4/3/2	0.5	0
Echo 1,2,4,5,6,16,17 (Lower Chalk Creek)	175	-6.5	1	8/7/6	4/3/2	0.5	0
Echo 3,10,11(Mainstem Weber River)	0.5	-6.5	1	4.5	4.5	1	1
Echo 12,13,14,15 (Silver Creek)	0	-6.5	1	5/4.5/4.5	5/4.5/4.5	0.1/0.5/0.5	1

[1]Numbers indicate the value used for elevation band1/elevation band2/elevation band 3. The same value is used for all three bands if only one value is listed.

A-3.2.12.1 GROUNDWATER PARAMETERS

In gaining streams, groundwater supports baseflow, which is the flow during the drier period of year with no inputs from snowmelt or precipitation. When the groundwater table is low, streams may become losing streams as water in the stream seeps back to the groundwater table through the stream bed. Other factors include the existing hydraulic conductivity, the ability of the stream bed to transmit water, and karst features such as sinkholes that may capture streamflow and direct it to the deep aquifers. In the SWAT model groundwater includes flow from soil water and shallow aquifers, and also the deep aquifer. These components consist of water entering the stream through lateral flow from the soil and additions from shallow groundwater.

SWAT groundwater parameters were adjusted by subbasin in the Echo Reservoir watershed to calibrate hydrology for the Silver Creek and Chalk Creek drainages separately. The hydrologic responses in Chalk Creek and Silver Creek drainages are different because of different geologic and groundwater characteristics. Silver Creek was particularly problematic to calibrate because of sinkholes that appeared in 2008, which captured the flow in Silver Creek. The stream is also a losing stream in the upper reaches (Laughlin 2009). Such flow losses, combined with the lack of daily data for the Park City point sources, make calibrating Silver Creek to a monthly and daily time step difficult. To address these issues, the hydraulic conductivity in the upstream subbasins was set to 5 mm/hour. The Park City point sources were combined into a single point source in subbasin 15, and a proportion of flow was removed to address the water loss and nutrient load loss associated with the upper Silver Creek reach to better match flow recorded at the USGS gage. Rockport groundwater parameters are shown in Table A-25 while Echo Reservoir watershed parameters used for monthly calibration are shown in Table A-26.

Table A-25. Groundwater Parameters Used in the Rockport Reservoir Watershed Model

Groundwater Parameter	Parameter Definition	Lower Weber River and Beaver Creek (subbasins 1-7)	Weber River (subbasins 8-18)
SHALLST (mm)	Initial depth of water in the shallow aquifer	1000	1000
DEEPST (mm)	Initial depth of water in the deep aquifer	9000	9000
GW_DELAY (days)	Groundwater delay	7.0	14.75
ALPHA_BF (days)	Baseflow alpha factor (a factor representing groundwater response to recharge)	0.1	0.0055
GWQMN (mm)	Threshold depth of water in the shallow aquifer required for return flow to occur	170.625	170.625
GW_REVAP (unitless)	Describes movement of water into the root zone from the shallow aquifer	0.1303	0.1303
REVAPMN (mm)	Threshold depth of water in the shallow aquifer for movement into the root zone or deep aquifer to occur	327.25	327.25
RCHRG_DP (unitless)	Deep aquifer percolation fraction	0.05	0.05
GWHT (m)	Groundwater height	1.00	1.00
LONG-TERM GROUNDWATER[1]	Describes the long-term groundwater contribution		

[1] The long-term groundwater parameter was added in the calibration phase and is not available in the ArcSWAT interface.

Table A-26. Groundwater Parameters Used in the Echo Reservoir Watershed Model

Groundwater Parameter	Parameter Definition	Value
SHALLST (mm)	Initial depth of water in the shallow aquifer	1000
DEEPST (mm)	Initial depth of water in the deep aquifer	9000
GW_DELAY (days)	Groundwater delay	31
ALPHA_BF (days)	Baseflow alpha factor (a factor representing groundwater response to recharge)	0.048
GWQMN (mm)	Threshold depth of water in the shallow aquifer required for return flow to occur	0
GW_REVAP(unitless)	Describes movement of water into the root zone from the shallow aquifer	0.02
REVAPMN (mm)	Threshold depth of water in the shallow aquifer for movement into the root zone or deep aquifer to occur	1.00

Table A-26. Groundwater Parameters Used in the Echo Reservoir Watershed Model

Groundwater Parameter	Parameter Definition	Value
RCHRG_DP (unitless)	Deep aquifer percolation fraction	0.050
GWHT (m)	Groundwater height	1.00
LONG-TERM GROUNDWATER[1]	Describes the long-term groundwater contribution	0.005[2]

A-3.2.13 Channel Characteristics

A-3.2.13.1 CHANNEL ROUTING PARAMETERS (RTE)

Adjustments to the channel routing are done primarily through channel dimensions: width to depth ratio and channel slope and are important in calibrating hydrology. SWAT generates initial estimates of the channel parameters using the ArcMap programs, the stream layer, and the DEM. These parameters were adjusted by subbasin in both the Rockport Reservoir and Echo Reservoir watersheds. The adjustments primarily affect the time of concentration, which will affect timing and quantity of peak flows and helped improve model calibration, particularly for timing of peak flows and instream sediment dynamics. Tables A-27 and A-28 show the routing parameters used for Rockport Reservoir and Echo Reservoir watershed models, respectively.

Table A-27. Routing Parameters Used in the Rockport Reservoir Watershed Model

Subbasin	Average Width of Main Channel at top of Bank (m)	Depth of Main Channel from Top of Bank to Bottom (m)	Average Slope of Main Channel along the Channel Length (m/m)	Manning's Roughness coefficient, n, for Main Channel	Channel Width to depth Ratio
1	74	1.93	0.001	0.014	38.23
2	69	1.84	0.012	0.014	37.37
3	66	1.79	0.005	0.014	36.84
4	32	1.10	0.010	0.014	28.84
5	10	0.50	0.006	0.014	19.37
6	23	0.88	0.016	0.014	25.85
7	17	0.72	0.028	0.014	23.38
8	51	1.51	0.010	0.014	33.78
9	13	0.62	0.038	0.014	21.69
10	44	1.36	0.014	0.014	32.07
11	21	0.83	0.017	0.014	25.04
12	9	0.46	0.046	0.014	18.69
13	11	0.54	0.046	0.014	20.22
14	32	1.11	0.016	0.014	29.04
15	30	1.06	0.011	0.014	28.36
16	25	0.93	0.043	0.014	26.55
17	19	0.79	0.016	0.014	24.44
18	13	0.61	0.039	0.014	21.57

Table A-28. Routing Parameters Used in the Echo Reservoir Watershed Model

Subbasin	Average Width of Main Channel at Top of Bank (m)	Depth of Main Channel from Top of Bank to Bottom (m)	Average Slope of Main Channel along the Channel Length (m/m)	Manning's Roughness Coefficient, n, for Main Channel	Channel Width to Depth Ratio
1	7.5	0.94	0.007	0.014	7.97
2	2	0.74	0.017	0.014	2.68
3	15	2.07	0.001	0.014	7.25
4	3	1.26	0.011	0.014	2.37
5	3.5	1.44	0.011	0.014	2.44
6	4	1.73	0.007	0.014	2.31
7	2	1.06	1.067	0.014	2.31
8	2	0.77	0.027	0.014	2.57
9	1.5	0.90	0.022	0.014	1.67
10	7	1.21	0.005	0.014	5.83
11	15	0.78	0.019	0.014	19.11
12	3	0.91	0.017	0.014	3.30
13	2	0.71	0.002	0.014	2.80
14	2	0.64	0.012	0.014	3.01
15	1.5	0.43	0.099	0.014	3.47
16	1.5	0.53	0.046	0.014	2.80
17	2	0.73	0.011	0.014	2.74

A-3.2.14 Channel Erodibility and Nutrients

SWAT allows users to specify parameters to describe channel erodibility, which is based on channel bed and bank materials. Included in these parameters are channel cover to describe the amount of vegetation on the stream bed and a monthly channel erosion factor that allows the user to increase erosion during certain months of the year. SWAT also contains four channel erosion equations to choose from based on channel and sediment types (Table A-29). SWAT also allows the user to specify organic nitrogen and organic phosphorus in the channel sediment (Table A-30). These parameters were adjusted in the Chalk Creek subbasins to account for human activities such as oil and gas development, past grazing practices, logging and farming, and development activities that have accentuated channel erosion in a drainage that is also naturally more erodible. Such adjustments make the SWAT output better match loads calculated from water quality monitoring samples. Channel erodibility factors in the Rockport Reservoir watershed model were not increased from the default values, which are the minimal values allowed because the initial model simulations overestimated sediment and nutrients.

Table A-29. Channel Erodibility Factors Used in Echo Reservoir Watershed Model

Subbasin	Channel Erodibilty Factor (unitless)[1]	Equation used for Sediment Routing
1	0	1[2]
2	0.1	2[2]
3	0	1
4	0	1
5	0	1
6	0	1
7	1	2
8	0	1
9	1	2
10	0	1
11	0	1
12	0	1
13	0	1
14	0	1
15	0	1
16	1	2
17	0	1

[1] The CH_ERODMO was applied for all months.

[2] 1= Simplified Bagnold Equation, 2=Kodatie Model

Table A-30. Channel Nutrient Concentrations Used in Echo Reservoir Watershed Model

Subbasin	Organic Nitrogen Concentration in the Channel Sediments (ppm)	Organic Phosphorus Concentration in the Channel Sediments (ppm)
1	0	5.15
2	0	6.37
3	0	7.87
4	0	5.9
5	0	8.17
6	0	7.8
7	0	6.37
8	0	5.32
9	0	5
10	0	5.57
11	0	5.28
12	0	5.57

Table A-30. Channel Nutrient Concentrations Used in Echo Reservoir Watershed Model

Subbasin	Organic Nitrogen Concentration in the Channel Sediments (ppm)	Organic Phosphorus Concentration in the Channel Sediments (ppm)
13	0	5.02
14	0	5.55
15	0	6.09
16	0	5
17	0	5

A-3.3 Model Calibration and Validation

A-3.3.1 Hydrology

SWAT generates surface water hydrology using a DEM and weather data from weather stations in or near the watershed. The curve number approach was chosen to estimate runoff volume from the watershed, while a modified rational method was used to calculate a peak flow. The algorithms used in the SWAT model to generate hydrology are explained in detail in Neitsch et al. 2009. Measured USGS flow data and BOR data for inflow and outflow at the reservoirs are used to calibrate the model.

The USGS gages used for calibration were the Weber near Coalville (10130500), Silver Creek at Silver Creek Junction (10129900), Chalk Creek near Coalville (10131000) and the Weber near Oakley (10128500). In addition, the BOR provided estimates of total inflow to Rockport Reservoir and Echo Reservoir, which were used for calibrating inflow to the reservoirs. These estimates are calculated from reservoir volume. Calibrating hydrology was completed in Rockport Reservoir and Echo Reservoir watersheds separately because the watersheds were separate project areas for SWAT.

Rockport Reservoir had only two gages with a dataset that included 1998-2011. The Weber at Oakely gage was used to calibrate hydrology at subbasin 8 in the Rockport Reservoir watershed while the inflow estimates from the BOR were used to calibrate flow into the reservoir. The Weber River at Oakely gage is located above the Weber-Provo diversion, but because the outflow from subbasin 8 is used for calibration, the flow diverted is returned to better match flow measured at the gage. The outflows from Rockport Reservoir are known and included in the Echo Reservoir watershed as a point source.

In the Echo Reservoir watershed, Silver Creek was calibrated at the Silver Creek gage, located in subbasin 13. The Weber mainstem above Chalk Creek was calibrated at the Weber River near Coalville gage in subbasin 10. Chalk Creek was calibrated at the Chalk Creek near Coalville gage in subbasin 6. The inflow to Echo Reservoir was calibrated at subbasin 3 using the BOR estimated inflow data (Figure A-14).

The calibration was done as a comparison of model output to measured discharges in the subbasin where the gage is located, measured as a percent. The monthly average values were used for calibration. The hydrology calibration was based on comparing the flow amounts measured to flow simulated in SWAT between the years 2002 and 2007. Model year 2007 was used for the calibration, with 2004 used as validation. The Nash-Sutcliffe efficiency (NSE) value was also calculated for the 2002-2007 (Table A-31). This value determines how well the model matched the existing data. According to Moriasi et al.

(2007), an NSE value of at least 0.5 indicates a satisfactory calibration. An efficiency value of 1 indicates a perfect match between observed and modeled values.

These watersheds are extremely complex. Weather and elevation are important in generating hydrologic responses. There is a substantial elevation difference in both watersheds, neither of which have a long-term weather station in the upper watershed. The weather stations that do exist are located in the lower elevation valley areas. Additionally, the groundwater contribution and baseflow were not well characterized. As such, the model developer, Dr. Srinivasan, was approached to provide assistance. Dr. Srinivasan performed an initial calibration of hydrology for the SWAT models for Rockport Reservoir and Echo Reservoir to monthly averages using the SWAT-CUP program, and added a long-term groundwater component to the calibration parameters. This variable was not available in SWAT when the calibration was completed in 2012. Hydrology was calibrated primarily by adjusting the snow parameters and temperature and precipitation lapse rates as well as groundwater parameters.

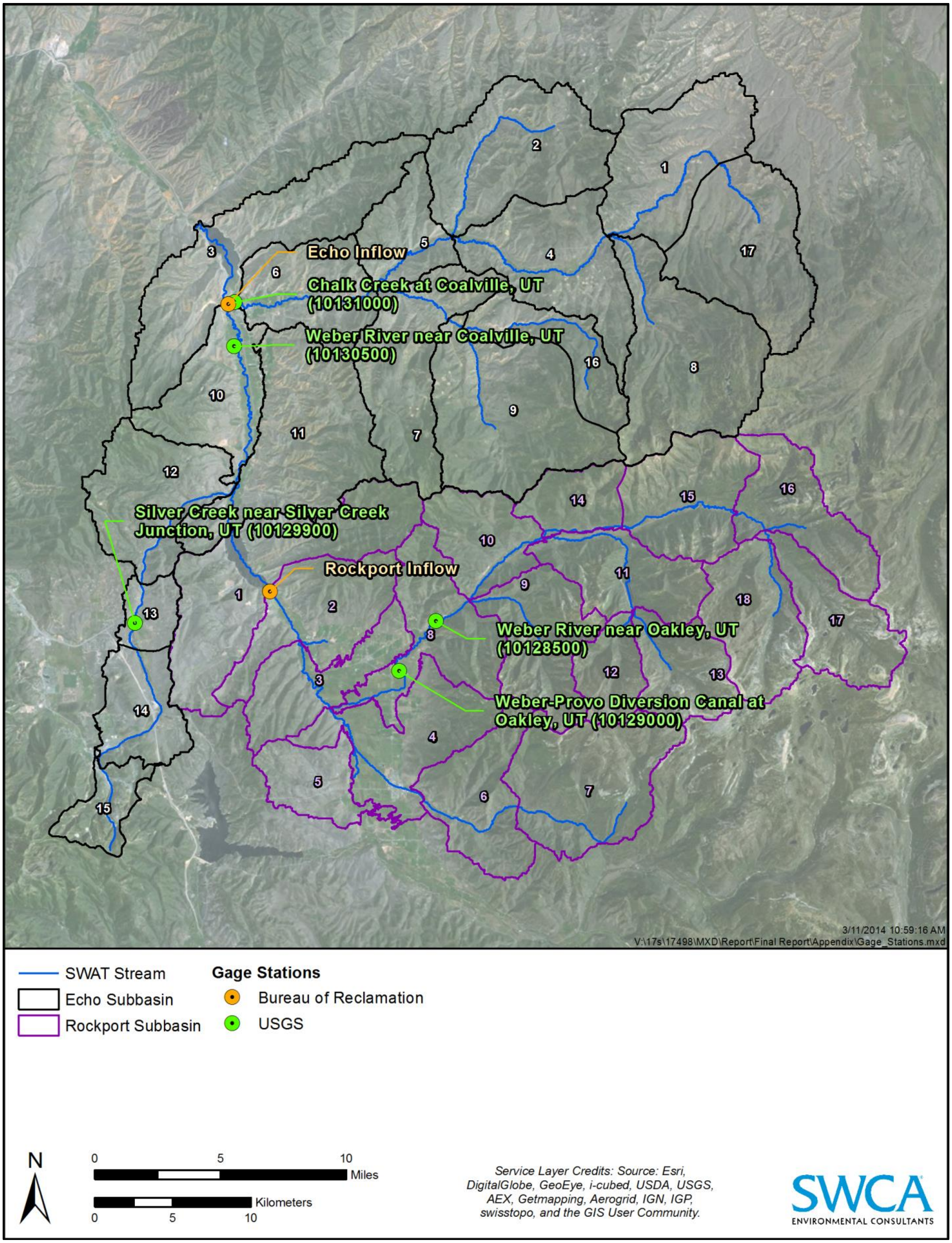

Figure A-14. Location of stream gages in the Rockport Reservoir and Echo Reservoir subbasins.

As noted earlier, the Silver Creek drainage has areas where the stream contributes to groundwater as a losing stream or sinkholes and underlying geology allow water to move into the deep aquifer. The calibrations show that the Silver Creek (subbasin 13) simulated nutrient loads are higher than the observed values. However, the flows are small enough that small increases in nutrients can translate into large proportional increases. The calibration is strong in Echo Reservoir subbasins 3 and 10 because the outflow from Rockport Reservoir is measured and is a large proportion of the total flow in the Weber mainstem in between the reservoirs. In addition, the BOR back-calculates the inflow from volume estimated using bathymetry. The bathymetry may change with sediment deposition occurring over the years, reducing the accuracy of inflow measurements. The minimum value for a satisfactory calibration was achieved for subbasin 1 (the inflow) to Rockport Reservoir and all subbasins used for calibration in the Echo Reservoir watershed. The results of the calibration statistics are shown in Table A-31.

Table A-31. Hydrologic Calibration Results for Rockport and Echo Reservoir Watershed Models

SWAT Generated Output From Subbasin	Measured Flow	Percent of Measured Flow 2002-2007	Percent of Measured Flow 2007	Nash-Sutcliffe Efficiency value (2002-2007)	Performance Rating for the Nash-Sutcliffe Efficiency Value[1]
Rockport 8	USGS Weber at Oakley	96%	113%	0.87	Very good
Rockport 1	BOR calculated inflow	93%	94%	0.75	Very good
Echo 3	BOR calculated inflow	97%	105%	0.77	Very good
Echo 6	USGS Chalk Creek at Coalville	107%	127%	0.63	Satisfactory
Echo 10	USGS Weber River at Oakley	90%	96%	0.85	Very good
Echo 13	USGS Silver Creek at Silver Creek Junction	141%	158%	0.52	Satisfactory

[1]The Nash-Sutfliffe efficiency values are from Moriasi et al. 2007.

A-3.3.2 Nutrients

Calibration for nutrient loads was completed for nitrate and total phosphorus. Calibration was not done for total nitrogen because the water quality monitoring dataset is much stronger for nitrate. SWAT output was used to estimate the loads entering the reservoir from each of the tributaries. For the Rockport Reservoir watershed, nutrient loads were calibrated at the inflow. The SWAT simulated loads were compared to measured loads at locations where data were available. For the Echo Reservoir watershed, nutrient loads were calculated for Chalk Creek at the Coalville/Chalk Creek USGS gage (and combined with loads from the Coalville WWTP), the Weber River at the Coalville/Weber River USGS gage, and Echo Reservoir inflow using BOR estimated flow data into the reservoir. The simulated loads were then compared to calculated loads from water quality data at each location (Table A-32). Calibration was done by adjusting the nutrient-related and erosion-related parameters noted in previous sections. The primary adjustments were to initial soil nutrient concentrations, channel erodiblity factors, and urban connectivity to streams. These calibration efforts are reflected in the final tables discussed in section 2.2. It should be noted that water quality data during storm events in the Rockport and Echo watersheds was not available. As such, loads produced by storm events were not effectively captured and therefore it is unknown to what extent the model matches the total load. Improvement of the calibration requires additional stormwater monitoring.

Table A-32. Nutrient Calibration Results for Echo Reservoir Watershed SWAT Model, Spring 2007 (April 1–July 15)

SWAT Subbasin	Total Phosphorus Load based on Measured data (kg)	Total Phosphorus Load based on SWAT Output (kg)	Total Nitrate Load based on Measured data (kg)	Total Nitrate Load based on SWAT Output (kg)
Rockport 2 (Weber River)	1,790	1,889	11,924	9,775
Echo 6 (Chalk Creek)	1,056	1,070	8,702	8,044
Echo 10 (Weber River at Coalville)	864	1,775	6,693	8,725
Echo 3 (Total Echo Reservoir watershed)	2,000	2,865	16,006	16,858

[1]Water quality data used to calculate this load does not appear to be representative of spring flow conditions.

A-4. RESERVOIR MODEL: BATHTUB

A-4.1 General Model Description

The BATHTUB reservoir model was developed by the U.S. Army Corps of Engineers as a sophisticated empirical model for predicting eutrophication in reservoirs. The model predicts nutrient concentrations, chlorophyll a, Secchi depth (water column transparency), and other eutrophication indices in a spatially segmented reservoir under steady-state conditions (Walker 1999).

Model inputs include reservoir morphometry (mean depth, length, width, and mixed-layer depth), hydraulic connectivity (between reservoir segments and tributaries), tributary water quality (total nutrients, dissolved nutrients, and flow), climatic parameters (precipitation and evapotranspiration), and atmospheric deposition of nutrients. The model uses empirical equations for physical processes, including advective transport, diffuse transport, and nutrient sedimentation to predict nutrient concentrations and reservoir water quality.

A-4.2 Model Inputs and Assumptions for Rockport Reservoir and Echo Reservoir

The BATHTUB model was set up for five climatic conditions and subsequent reservoir conditions, which represent expected variability in both climate and management. These conditions represent a dry year, an average year, and one wet year with similar water level conditions at both Rockport Reservoir and Echo Reservoir.

- **Condition A**: A dry water year; note that although 2004 was a dry year for most of the Weber River basin, the flows above Rockport Reservoir are higher than in 2007.
- **Condition B**: An average water year (2007)
- **Condition C**: A wet water year (2011)

The BATHTUB model inputs are climate variables, definition of the stratification season, reservoir and segment shape, internal nutrient loading, and water quality parameters for tributaries. Each set of inputs (above) had specific sources and required individual assumptions which are discussed below. The model was run for the stratification season. The period during the summer season when the reservoir is stratified is the most critical for DO concerns because the thermal stratification prevents oxygen from being introduced into the lower parts of the reservoir (hypolimnion) through mixing. Algal growth also occurs during the summer season, the decomposition of which leads to low DO in the hypolimnion. Calibration of the BATHTUB model requires estimates of reservoir water quality parameters, which are discussed below.

A-4.2.1 Stratification Season

It was assumed that the reservoirs are thermally stratified from May 15 to September 30. These dates were selected based on evaluation of all of temperature and DO profile data available for the reservoirs and result in a 137-day stratification season. Dissolved oxygen and temperature profile data from the years 2004, 2007, and 2011 were used to further validate the use of this stratification season assumption for all of the conditions modeled (see Figure 11 in the Data Summary Report).

These dates were used to determine reservoir elevation at the beginning and ending of stratification using data available from the BOR (2011). Elevation at both reservoirs is significantly lower at the end of the season for 2004 and 2007, though the change in elevation is greater at Echo Reservoir because it only stores a one-year supply of water whereas Rockport Reservoir stores a two-year supply. In 2007, the water level in Rockport Reservoir began at 1,839.4 meters and ended at 1,829.6 meters (Figure A-15). 2011 was a wet year, and end-of-season elevation was slightly higher than at the beginning for Echo Reservoir and significantly higher for Rockport Reservoir.

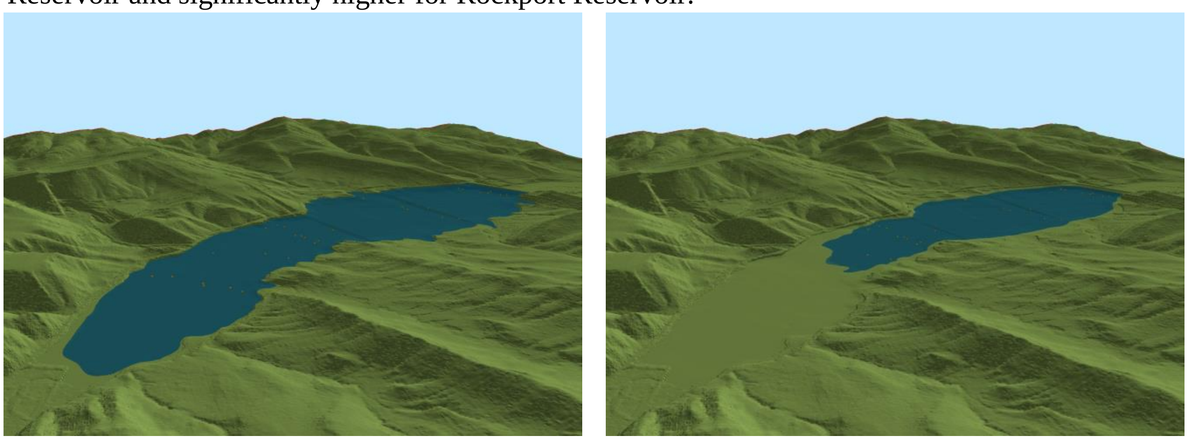

Figure A-15. Rockport Reservoir water level on May 15, 2007 (1,839.4 meters), and September 30, 2007.

A-4.2.2 Reservoir Shape and Segmentation

Rockport Reservoir and Echo Reservoir were each divided into a Mid-Upper Pool segment and a Dam segment (Figures A-16 and A-17). Chalk Creek and Weber River are tributaries to the Echo Reservoir Mid-Upper Pool segment; Weber River is the only tributary to the Mid-Upper Pool for Rockport Reservoir. Tributary inputs for each of the Dam segments are based on direct discharge into the reservoirs. Reservoir shape includes seasonal starting and ending elevations; average length, width, and depth; surface area; depth at stratification of mixed layer and hypolimnion; and volume (Table A-33 and Table A-34). An updated (2007) bathymetry dataset was available for Rockport Reservoir but no bathymetry data were available for Echo Reservoir. Depth measurements collected throughout Echo Reservoir in summer 2007 by the Weber Basin Water Conservancy District were used, together with contour data available at the surface of the reservoir, to generate a simplistic bathymetry dataset for purposes of estimating reservoir shape at varying elevations. Spatial analysis tools in ArcGIS, including volumetric estimation, were used to calculate all reservoir dimensions except hypolimnetic depth. Hypolimnetic depth was determined through examination of depth profiles of temperature and DO collected during each year at various times during the stratification season (see Figure 11 in the Data Summary Report). From these data the percent of the total depth that is represented by the hypolimnion and metalimnion was determined for both the Mid-Upper Pool and Dam segments.

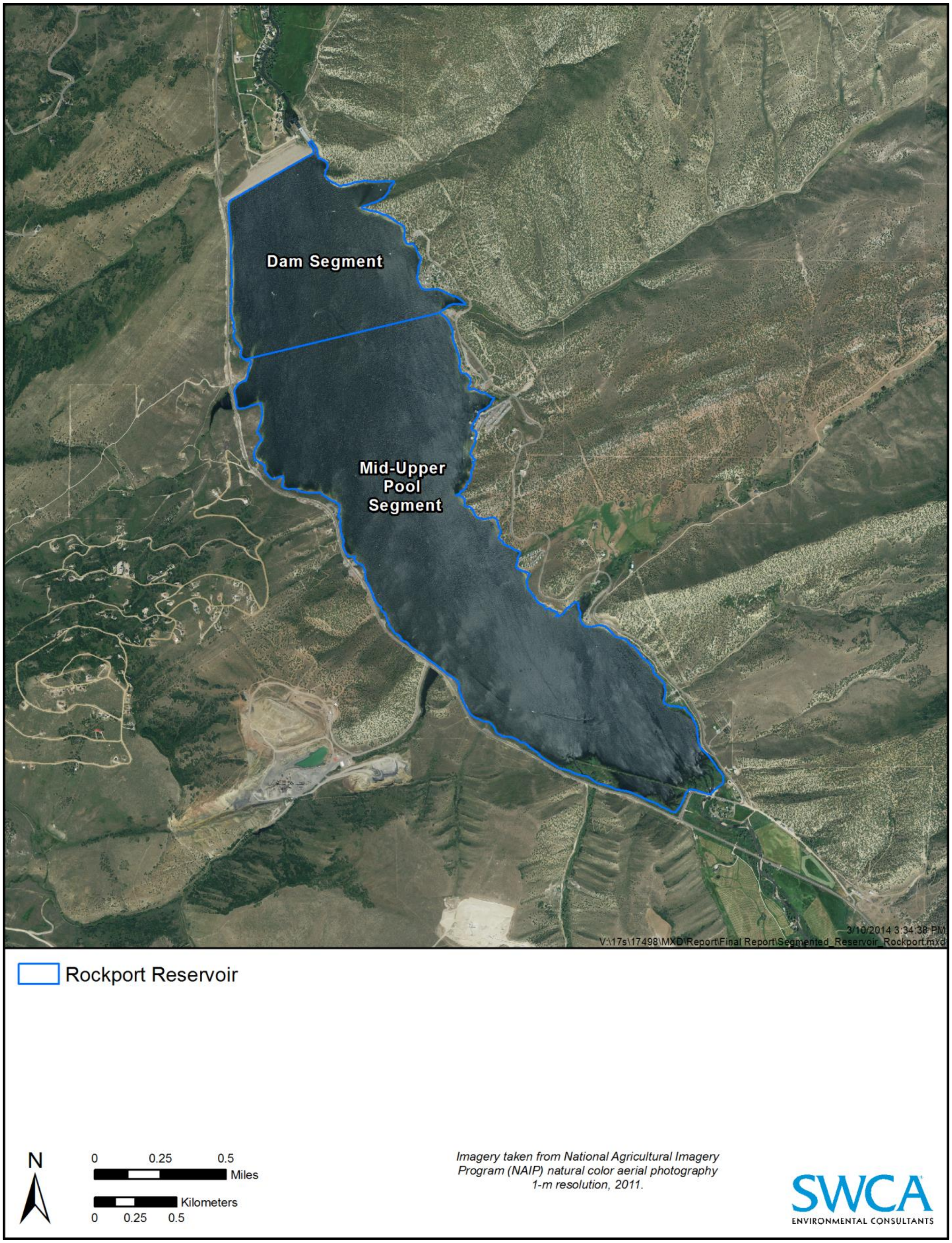

Figure A-16. Rockport Reservoir model segments.

Figure A-17. Echo Reservoir model segments.

Table A-33. Summary of Reservoir Characteristics for Rockport Reservoir BATHTUB Model

	2004	2007	2011
Dam Segment			
Starting elevation on May 15 (m)	1,835.0	1,839.4	1,827.8
Ending elevation on September 30 (m)	1,833.2	1,829.6	1,838.1
Starting length (km)	1.05	1.06	1.02
Starting width (km)	0.94	1.03	0.86
Starting depth (m)	22.18	24.23	17.27
Starting surface area (km^2)	0.99	1.09	0.89
Depth of Mixed layer at stratification (m)	8.00	1.46	1.00
Hypolimnetic depth at stratification (m)	12.18	12.03	9.27
Volume (hm^3)	21.96	26.52	15.30
Mid-Upper Pool Segment			
Starting elevation on May 15 (m)	1,835.0	1,839.4	1,827.8
Ending elevation on September 30 (m)	1,833.2	1,829.6	1,838.1
Starting length (km)	2.85	3.61	1.87
Starting width (km)	0.83	0.88	0.82
Starting depth (m)	11.58	12.46	8.86
Starting surface area (km^2)	2.36	3.18	1.53
Depth of mixed layer at stratification (m)	8.00	1.90	1.00
Hypolimnetic depth at stratification (m)	1.58	3.35	0.86
Volume (hm^3)	27.37	39.62	13.55

Table A-34. Summary of Reservoir Characteristics for Echo Reservoir BATHTUB Model

	2004	2007	2011
Dam Segment			
Starting elevation on May 15 (m)	1,691.3	1,694.3	1,686.0
Ending elevation on September 30 (m)	1,679.3	1,677.5	1,686.7
Average length (km)	1.25	1.26	1.23
Average width (km)	0.68	0.70	0.65
Average depth (m)	18.89	21.19	14.77
Surface area (km^2)	0.85	0.88	0.80
Depth of mixed layer at stratification (m)	4.00	4.57	1.00
Hypolimnetic depth at stratification (m)	8.89	11.99	9.77
Volume (hm^3)	16.14	18.70	11.79

Table A-34. Summary of Reservoir Characteristics for Echo Reservoir BATHTUB Model

	2004	2007	2011
Mid-Upper Pool Segment			
Starting elevation on May 15 (m)	1,691.3	1,694.3	1,686.0
Ending elevation on September 30 (m)	1,679.3	1,677.5	1,686.7
Average length (km)	4.20	5.15	3.47
Average width (km)	1.00	0.95	0.96
Average depth (m)	11.29	12.50	8.16
Surface area (km^2)	4.22	4.87	3.34
Depth of mixed layer at stratification (m)	4.00	3.84	1.00
Hypolimnetic depth at stratification (m)	1.29	3.30	3.16
Volume (hm^3)	47.59	60.88	27.30

A-4.2.3 Atmospheric and Climate Parameters

Atmospheric and climate parameter inputs to BATHTUB are precipitation, evaporation, and nutrient deposition (Table A-35). Precipitation data were downloaded from the Utah State University Climate Center: specifically, sites USC00429165 and USC00422385 for Rockport Reservoir and Echo Reservoir, respectively (USUCC 2011). Monthly values are the sum of precipitation for all days per month for each of the three conditions. Evaporation data were downloaded from the Western Regional Climate Center (WRCC 2011). Values represent monthly averages for Wanship Dam for the entire period of record from 1955 to 2005; thus, values are the same for each of the five conditions.

Atmospheric deposition of nitrogen data were taken from the National Atmospheric Deposition Program website (NADP 2011). Values were estimated from the NADP atmospheric deposition map by year. Phosphorus deposition values were not available from NADP; these were obtained from California Department of Environmental Protection (CDEP 2011), who reported an annual phosphorus deposition rate of 0.05 kg/ha/yr from a study at Lake Tahoe, California. All phosphorus values went into this pool and no values were put into the orthophosphate (ortho-P) category. All annual values for nitrogen and phosphorus deposition were divided by 12 to derive monthly rates, which assumes deposition rates are not seasonally variable.

Table A-35. Summary of Atmospheric and Climate Variables Used in BATHTUB Models

	2004	2007	2011
Rockport			
Precipitation (m)	0.15	0.02	0.14
Evaporation (m)[1]	0.73	0.73	0.73
Total phosphorus deposition (mg/m^2-yr)	1.89	1.89	1.89
Total n deposition (mg/m^2-yr)	93.74	74.97	74.97
Echo Reservoir			

Table A-35. Summary of Atmospheric and Climate Variables Used in BATHTUB Models

	2004	2007	2011
Precipitation (m)	0.12	0.12	0.12
Evaporation (m)	0.73	0.73	0.73
Total phosphorus deposition (mg/m^2-yr)	1.89	1.89	1.89
Total nitrogen deposition (mg/m^2-yr)	74.97	74.97	74.97

[1] Evaporation rates are measured in units of meters for the season. They are applied to the average area of the reservoir during that season to estimate total evaporative volume lost.

A-4.2.4 Tributary Water Quality

Tributary inputs for BATHTUB are flow, total and inorganic nitrogen, total phosphorus, orthophosphate, and chloride. Water quality parameters were summarized for each year (2004, 2007, and 2011) based on three seasons: early spring (April 1–May 15), late spring (May 16–July 15), and summer (July 15–September 30). Additionally, The BATHTUB model uses the mean coefficient of variation (CV) as a measure of error. The CV is calculated as the standard error divided by the mean result value. Where possible (sample size > than 1) the CV was calculated and used in model calibration.

The primary tributary input for Rockport Reservoir is the Weber River. In addition, direct runoff from the area surrounding the reservoir was input as a separate source. Measured water quality and flow for each of the three seasons (early spring, late spring, and summer) were used as direct inputs to the Rockport Reservoir BATHTUB models Table 56). These loads may be updated once nutrients are calibrated for the SWAT model output from the Rockport Reservoir watershed. SWAT output will also be used in the source identification portion of the TMDL to assess the relative load contribution of various nonpoint sources to the reservoir.

Tributary inputs to Echo Reservoir are the Weber River, Chalk Creek, and the direct runoff from the area surrounding the reservoir. Modeled (SWAT) loads for tributaries to Echo Reservoir for the dry (2004) and average (2007) conditions were used as inputs to the BATHTUB models (Table A-36). Loads were converted to concentrations using measured flow because the gage data for both tributaries is very good. The modeled loads were found to be more accurate than loads calculated with measured water quality data because the measured data does not incorporate the loads from storm events, an important load during the dry and average flow conditions. Further, there are multiple known loads to the Echo Reservoir watershed including Silver Creek WWTP, Coalville WWTP, and the output from Rockport Reservoir that could not be accounted for in calculated loads. The SWAT model was used to route these loads to the reservoir to determine the amount of nutrients lost between the source and the reservoir (e.g. delivery ratio). The SWAT model was not calibrated for the high flow event of 2011. Instead, tributary water quality and flow data were used directly as inputs for the 2011 Echo Reservoir BATHTUB model (Table A-37).

Table A-36. Tributary Inputs (Weber River and Direct Drainage) to Rockport Reservoir BATHTUB Model

	2004	2007	2011
Weber River			
Flow (hm^3/season)	52.1	45.6	262.2

Table A-36. Tributary Inputs (Weber River and Direct Drainage) to Rockport Reservoir BATHTUB Model

	2004	2007	2011
Total Phosphrous (µg/L)	57	45	97
Orthophosphate (µg/L)	21	13	8
Total Nitrogen (µg/L)	339	343	253
Inorganic Nitrogen (µg/L)	242	272	141
Direct Drainage			
Flow (hm^3/season)	6.3	5.5	31.6
Total Phosphrous (µg/L)	40	56	400
Orthophosphate (µg/L)	4	6	14
Total Nitrogen (µg/L)	642	370	732
Inorganic Nitrogen (µg/L)	583	289	189

Table A-37. Tributary Inputs to Echo Reservoir BATHTUB model

	2004	2007	2011
Weber River			
Flow (hm^3/season)	62.6	73.0	324.3
Total Phosphrous (µg/L)	74	53	44
Orthophosphate (µg/L)	37	41	34
Total Nitrogen (µg/L)	575	419	393
Inorganic Nitrogen (µg/L)	287	222	133
Chalk Creek			
Flow (hm^3/season)	19.8	31.1	160.3
Total Phosphrous (µg/L)	24	44	54
Orthophosphate (µg/L)	9	8	16
Total Nitrogen (µg/L)	215	377	276
Inorganic Nitrogen (µg/L)	196	346	119
Direct Drainage			
Flow (hm^3/season)	3.0	4.8	25
Total Phosphrous (µg/L)	41	39	44
Orthophosphate (µg/L)	41	27	34
Total Nitrogen (µg/L)	62	85	342
Inorganic Nitrogen (µg/L)	62	51	117

A-4.2.5 Reservoir Water Quality

BATHTUB was populated with water quality data for each reservoir segment and condition using available data for purposes of model calibration (Table A-38). Individual parameter values represent summer season averages using only values from samples taken at the surface. Surface samples were used because they were more readily available compared to stratified reservoir samples and because surface nutrients contribute more to algal growth. Each reservoir was divided into two segments representing inflow and near dam conditions. Reservoir water quality data used for model calibration include total nitrogen and total phosphorus, organic nitrogen, orthophosphate, chlorophyll a, Secchi depth, hypolimnetic and metalimnetic depth (discussed below), and chloride. Note that values for all inputs were not equally available for both reservoirs and segments.

Table A-38. Reservoir Surface Water Quality (Dam Segment)

	2004	2007	2011
Rockport Reservoir			
Total Phosphorus (µg/L)	37.0	18.3	32.2
Dissolved Phosphorus (µg/L)	32.1	16.6	No data
Estimated Total Nitrogen (µg/L)	369	382	348
Chlorophyll-a (µg/L)	2.2	1.6	0.8
Echo Reservoir			
Total Phosphorus (µg/L)	18.4	20.0	39.7
Dissolved Phosphorus (µg/L)	13.5	12.8	33.3
Estimated Total Nitrogen (µg/L)	657.1	413.5	714.9
Chlorophyll-a (µg/L)	1.6	3.8	1.5

A-4.2.6 Oxygen Depletion Rates

The rate of oxygen depletion during stratification in each reservoir for the three modeled conditions (dry, wet, and average) was calculated using DO profile data available for the dam segment of each reservoir. Due to the change in reservoir volume over the course of the stratification season, it was not possible to differentiate metalimnetic oxygen depletion (MOD) rates from hypolimnetic oxygen depletion rates. Rather, a combined oxygen depletion rate below the thermocline (metalimnion and hypolimnion) was calculated.

Water from beneath the thermocline is released from both reservoirs when the reservoirs are thermally stratified. Through this process some nutrients and oxygen are also released from the reservoirs. Net oxygen losses via water withdrawals from the hypolimnion were calculated using the hypolimnetic volume lost and the average DO concentration in the hypolimnion during the withdrawal period (Tables A-39 and A-40). The volume of the hypolimnion at each profile date was used to calculate the volume lost. The remaining change in hypolimnetic oxygen mass then represents oxygen depletion over the course of the stratification season. Oxygen depletion rates are calculated by dividing the net oxygen loss by the number of days between the two profiles. Whenever possible, profiles earlier in the stratification season. During the early part of the stratification season, the depletion of oxygen is limited by oxygen demand in the hypolimnion. Later in the stratification season, when oxygen levels are already low, oxygen depletion can be limited by the availaibty of oxygen itself. As a result, the oxygen depletion rates are lower even if oxygen demand remains high. Therefore, oxygen depletion rates calculated using profile data earlier in the season are more representative of the true oxygen demand that is linked to algal growth and nutrients in the upper water column.

Table A-39. Hypolimnetic Oxygen Depletion Calculations for Rockport Reservoir BATHTUB Model Calibration

	2004	2007	2011
Dam Segment			
Profile dates	**June 14/August 10**	**June 27/July 10**	**June 20/August 25**
Depth of thermocline at second profile (m)	10	4.7	8
Change in reservoir level between profiles (m)	-3.1	-6.25	+ 1.5
Change in hypolimnetic volume between profiles (1,000 m^3)	-3,612	-1,235	+ 9,161
Total oxygen mass at first profile (kg)	86,104	121,843	128,856
Oxygen lost or gained via water withdrawals or fill (kg)	-7,189	-44,596	+30,386
Total oxygen mass at second profile (kg)	18,793	101,242	83,304
Oxygen depletion rate (mg/m^3/day)	59.2	50.3	64.4

Table A-40. Hypolimnetic Oxygen Depletion Calculations for Echo Reservoir BATHTUB Model Input

	2004	2007	2011
Dam Segment			
Profile dates	**June 15/August 11**	**May 22/July 10**	**June 8/July 13**
Depth of thermocline at second profile (m)	7	5	3
Change in reservoir level between profiles (m)	-4	-4.6	+3
Change in reservoir volume between profiles (1,000 m^3)	-6,071	-5,288	+2,387
Total oxygen mass at stratification (kg)	64,437	110,036	135,435
Oxygen lost or gained via water withdrawals or fill (kg)	-6,800	-21,876	+15,233
Total oxygen mass at turnover	19,011	54,508	34,219
Oxygen depletion rate (mg/m^3/day)	53.8	49.5	58.0

A-4.3 Model Calibration

Model calibration is an important step in the modeling process. Separate BATHTUB models were developed and calibrated for each of the climate conditions (wet, average, and dry) for Rockport Reservoir and Echo Reservoir. BATHUB offers users a choice of several sub-models or sets of equations to simulate nutrients and chlorophyll a. Whenever possible, calibration was achieved by selecting the empirical sub-model for nutrients and chlorophyll a that best fit the data, recognizing that reservoir dynamics are largely driven by climatic conditions and management. Therefore, different combinations of empirical sub-models better represent the conditions of each reservoir during a dry, wet, and average year. The sub-models summarized in Table A-41 were found to best fit the dry, average, and wet conditions for Rockport Reservoir and Echo Reservoir. Once the best empirical sub-model was found, additional calibration to nutrient decay rates and oxygen depletion rates were made as needed. Nutrient decay rates were calibrated first and oxygen depletion rates were only calibrated if discrepancies remained between the measured oxygen depletion rates in the reservoir and the model predicted rates (Table A-42).

Table A-41. Empirical Sub-Models Selected for Reservoir BATHTUB Model of Rockport or Echo Reservoir

Parameter	Model Selected	Justification
Conservative substance	Not computed	Default and insufficient data
Total phosphorus	Second order, available total phosphorus (Echo 2004, 2007, 2011; Rockport Reservoir 2007 and 2011) First order (Rockport Reservoir 2004)	Default
Total nitrogen	Second order, available total nitrogen (Echo 2004, 2011; Rockport Reservoir 2011) First order (Rockport Reservoir 2004, 2007; Echo Reservoir 2007)	Reservoirs are co-limited
Chlorophyll *a*	P, N, Light, and Temperature	Reservoirs are co-limited.
Transparency	Chlorophyll-a and turbidity	Default
Longitudinal dispersion	Fischer-numeric	Default

Table A-42. Nutrient Decay Rates Calibration Coefficients used for BATHTUB Model of Reservoirs

Parameter	Rockport Reservoir	Echo Reservoir
Total Phosphorus	 2011: 3.1	2004: 2.7 2011: 4
Total Nitrogen	2011: 23.9	2004: 0.8

Reservoir water quality data are not used directly in the BATHTUB model but are used to validate the model assumptions and tributary input loads used to configure the reservoir model. Validation parameters included MOD (Figure A-28), total P, total N, and Chl a (Table A-43 and A-44).

Table A-43. Validation Parameter for BATHTUB Model of Rockport Reservoir (all units in µg/L)

Parameter	2004		2007		2011	
	Model	**Observed**	**Model**	**Observed**	**Model**	**Observed**
Total P	41.5	37.0	18.5	18.3	33.1	32.2
Dissolved P	–	32.1	–	16.6	–	No data
Ortho-P	12.1	No data	10.5	No data	12.2	No data
Total N	410.5	No data	394.2	487	356.8	No data
Inorganic N	–	230	–	148.3	–	142.6
Organic N	347	No data	325.5	No data	348	No data
Chlorophyll a	8.1	2.2	7.1	1.6	8.1	0.82

Table A-44. Validation Parameter for BATHTUB Model of Echo Reservoir (all units in µg/L)

Parameter	2004		2007		2011	
	Model	**Observed**	**Model**	**Observed**	**Model**	**Observed**
Total P	18.6	18.4	24.5	20.0	35.2	39.7
Dissolved P	–	13.5	–	12.8	–	33.3
Ortho-P	7.9	No data	11.4	No data	15.7	No data
Total N	347.5	No data	408	*614*	405.4	No data
Inorganic N	–	131	–	*90.6*	–	313.3
Organic N	292.5	No data	337.2	No data	392.5	No data
Chlorophyll a	5.7	1.6	7.6	3.75	10.1	1.5

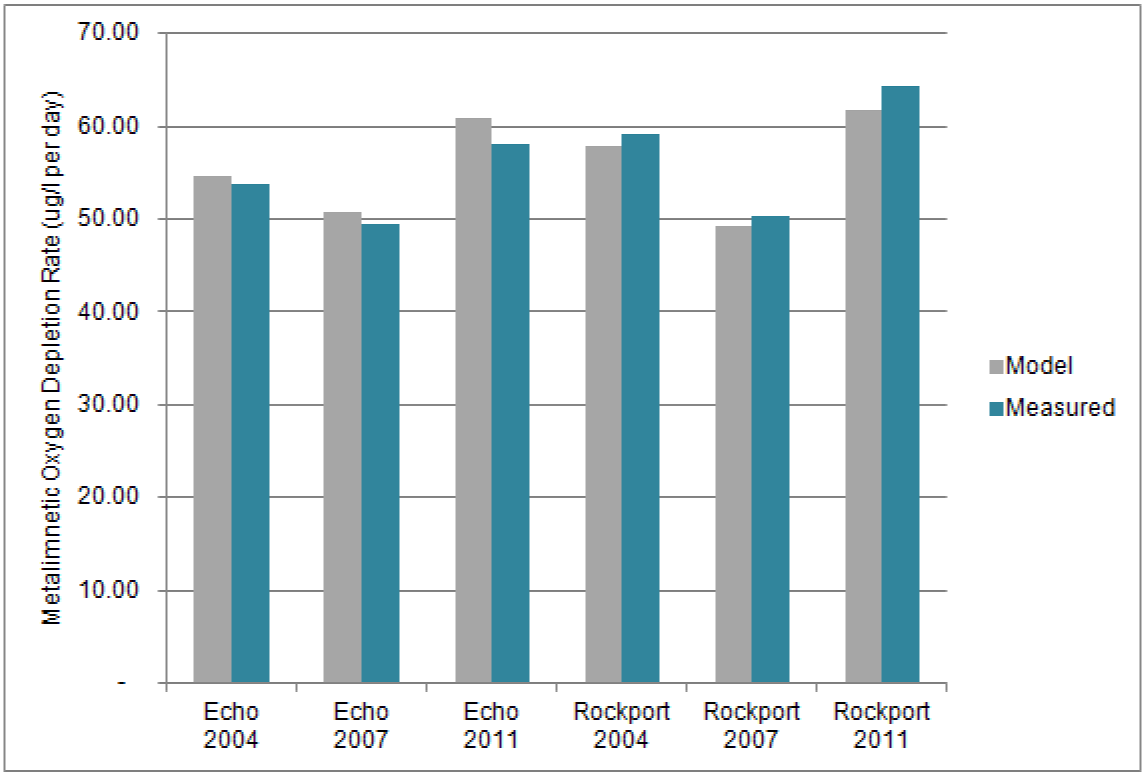

Figure A-18. Model validation of MOD rates for dam segment during stratification.

A-5. MODEL RESULTS

A-5.1 Current Nutrient Loads

The calculated total phosphorus and total nitrate loads to Rockport Reservoir under the average climatic and reservoir management conditions range from 2,337 to 3,230 kg/season and 13,969 to 16,279 kg/season respectively. The loads during the wet condition, represented by 2011, are significantly higher than the average condition (Tables A-45 and A-46). Rockport Reservoir received nearly four times the flow in 2011 as it did in 2004 and 2007. There are no representative 'dry' condition years for Rockport Reservoir and the flows into Rockport Reservoir in 2004, the dry year for Echo Reservoir, are higher than the flows in 2007, the average condition for Echo Reservoir. The total load is split relatively evenly between spring and summer.

Table A-45. Summary of Calculated Current Total Phosphorus Loads to Rockport Reservoir during the Spring (April 1 – July 15) and Summer Seasons (July 16 – September 30)

	Average (2004)	Average (2007)	Wet (2011)
Spring Loads			
Weber River	2,285	1,358	11,378
Direct Drainage	227	114	1,370
Total Watershed	2,512	1,471	12,748

Table A-45. Summary of Calculated Current Total Phosphorus Loads to Rockport Reservoir during the Spring (April 1 – July 15) and Summer Seasons (July 16 – September 30)

	Average (2004)	Average (2007)	Wet (2011)
Summer Loads			
Weber River	691	673	2,180
Direct Drainage	27	193	262
Total Watershed	717	866	2,442
Total Loads			
Weber River	2,976	2,031	13,558
Direct Drainage	254	306	1,632
Total Watershed	**3,230**	**2,337**	**15,190**

Table A-46. Summary of Current Total Nitrate Loads to Rockport Reservoir during the Spring (April 1 – July 15) and Summer Seasons (July 16 – September 30)

	Average (2004)	Average (2007)	Wet (2011)
Spring Loads			
Weber River	9,164	10,218	65,865
Direct Drainage	3,062	1,541	7,931
Total Watershed	12,226	11,759	73,796
Summer Loads			
Weber River	3,459	2,163	12,419
Direct Drainage	595	47	1,495
Total Watershed	4,054	2,210	13,914
Total Loads			
Weber River	12,623	12,381	78,284
Direct Drainage	3,657	1,588	9,426
Total Watershed	**16,279**	**13,969**	**87,710**

The average total phosphorus and total nitrate loads for Echo Reservoir under the average climatic and reservoir management conditions are 5,387 kg/season and 27,228 kg/season respectively. The loads during the dry condition, represented by 2004, are slightly lower and the loads during the wet condition, represented by 2011, are two to four times higher than the average condition (Tables A-47 and A-48). The total load is split relatively evenly between spring and summer; however, the source of loads during these two seasons is significantly different. The majority of the Chalk Creek load occurs during the spring, whereas the majority of the Weber River load occurs during the summer. This reflects the snow-melt dominated hydrology characterizing the Chalk Creek watershed in the spring and the release of water from Rockport Reservoir into the Weber River, primarily during the summer season. While there is significant flow into Rockport Reservoir during the spring period, this flow is primarily being retained in Rockport Reservoir for release later in the summer season.

Total loads are calculated as the sum of the spring (April 1-July 15) and summer (July 16- September 30) seasonal loads.

The seasonal loads are important because spring runoff and summer storm events tend to generate the majority of sediment and nutrients from these watersheds. Nutrient loads from the watershed are minimal during the winter, which is not a critical period for algal growth or oxygen depletion in the reservoirs.

Partitioning the load estimates into spring and summer seasons also highlights how loads change between the seasons. Over 50% of the total phosphorus load enters the reservoir during the spring, while just under 40% is delivered during the summer. The seasonal differences are also apparent in individual tributaries. As noted earlier, Chalk Creek contributes more of its total nutrient load during the spring, while summer releases from Rockport Reservoir increase the load from the Weber River during the summer. Chalk Creek delivers 30% of the total phosphorus entering Echo Reservoir in the spring and only 10% in the summer.

Table A-47. Summary of Current Total Phosphorus Loads to Echo Reservoir during the spring and summer seasons (April 1 – September 30)

	Dry (2004)	Average (2007)	Wet (2011)
Spring Loads			
Chalk Creek	345	1,070	8,130
Weber River	3,168	1,775	10,858
Direct Drainage	16	20	967
Total Watershed	3,529	2,865	19,955
Summer Loads			
Chalk Creek	134	285	750
Weber River	1,452	2,070	3,348
Direct Drainage	17	165	126
Total Watershed	1,603	2,521	4,223
Total Loads			
Chalk Creek	480	1,355	8,880
Weber River	4,620	3,845	14,206
Direct Drainage	33	186	1,093
Total Watershed	5,133	5,387	24,179

Table A-48. Summary of Current Total Nitrate Loads to Echo Reservoir during the spring and summer season (April 1 – September 30)

	Dry (2004)	Average (2007)	Wet (2011)
Spring Loads			
Chalk Creek	2,277	8,066	9,898
Weber River	10,186	8,728	25,584
Direct Drainage	138	90	2,278
Total Watershed	12,601	16,885	37,760
Summer Loads			
Chalk Creek	1,594	2,678	9,205
Weber River	7,806	7,512	17,449
Direct Drainage	51	153	655
Total Watershed	9,450	10,343	27,309
Total Loads			
Chalk Creek	3,871	10,745	19,103
Weber River	17,992	16,240	43,033
Direct Drainage	188	243	2,933
Total Watershed	**22,051**	**27,228**	**65,069**

The total loads are significantly lower than other estimated loads to Echo Reservoir presented in past studies (DWQ 2004). This difference relates to a significant reduction in phosphorus concentrations in both Chalk Creek and the Weber River since 2000. Figure A-19 shows the average concentrations of phosphorus in both tributaries in the late 1990s (the values used in previous load calculations) compared to all of the available data since 2001. After 2001, there are only a handful of data points that are above the historic average concentrations. Significant work on reducing nonpoint sources in the watershed, especially Chalk Creek, could explain the reduced nutrient concentrations. Other potential explanations could be changes in monitoring protocol such as inclusion or exclusion of storm events or changes in methods. Such potential explanations are beyond the scope of this project to explore. It was assumed that the current water quality data are representative of spring runoff and summer baseflow conditions in both tributaries.

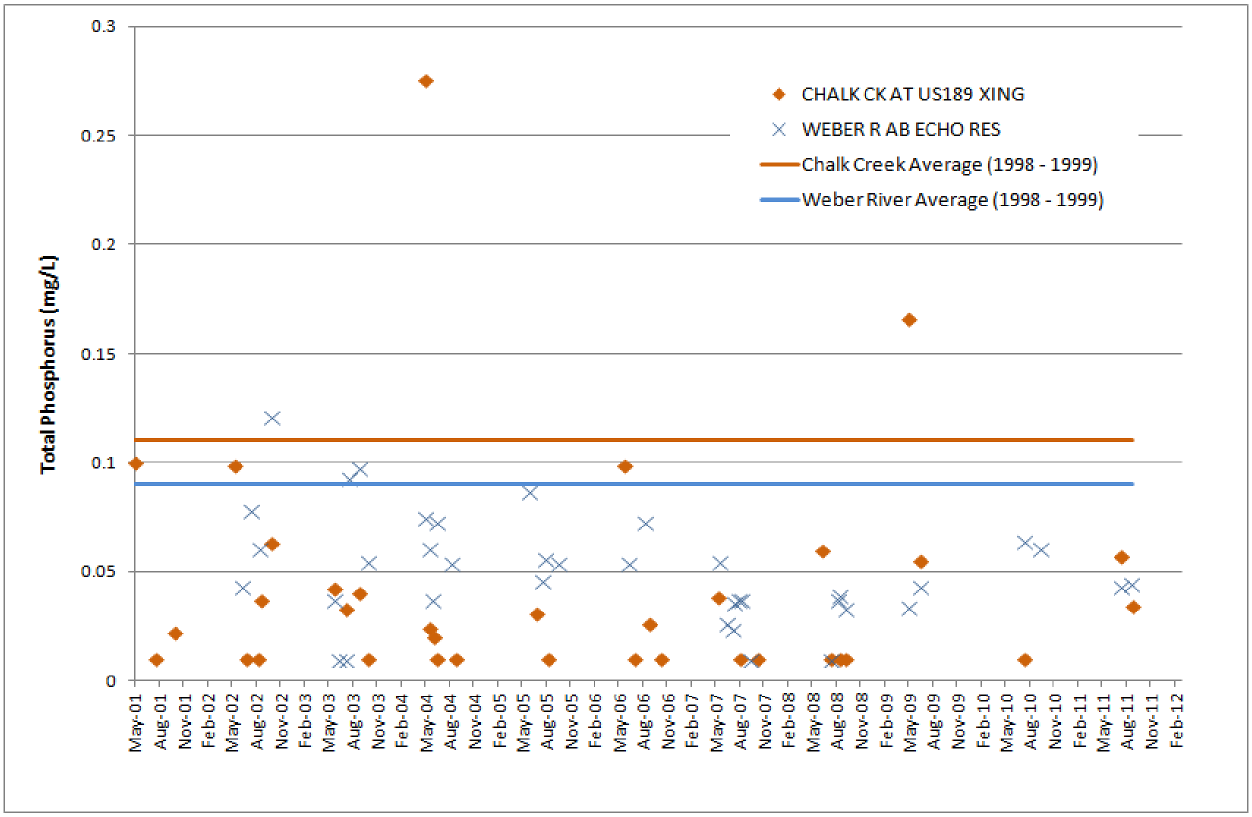

Figure A-19. Summary of total phosphorus data in Weber River from 2001 – 2012 and comparison to averages in the late 1990s.

A-5.2 Dissolved Oxygen Targets

Dissolved oxygen is important to the health and viability of the cold-water fishery beneficial use (3A), designated by the State of Utah for Rockport Reservoir and Echo Reservoir. High concentrations of DO (6.0–8.0 mg/L or greater) are necessary for the health and viability of fish and other aquatic life. Low DO concentrations (less than 4.0 mg/L) cause increased stress to fish species, lower resistance to environmental stress and disease, and result in mortality at extreme levels (less than 2.0 mg/L). Low DO in the reservoir is related to the decomposition of algae and other organic matter and subsequent depletion of DO in the hypolimnion.

A-5.2.1 Dissolved Oxygen Concentration Targets

The goal of the Rockport Reservoir and Echo Reservoir TMDLs is to increase concentrations of oxygen in the reservoir such that the designated beneficial uses are fully supported. Cold-water sport fish species are not known to reproduce in the reservoir, therefore the early life-stage criteria do not apply. The state DO criteria for all life-stages of cold-water fish are: 4.0 mg/L as a 1-day minimum, 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average.

All of these criteria are currently attained in the epilimnion of the reservoirs and violated in the hypolimnion of the reservoirs at the end of the summer stratification season. The State of Utah applies the 4.0 mg/l standard to a minimum of 50% of the water column in assessing attainability of this standard in deep stratified lakes and reservoirs. In addition, the epilimnion in each reservoir routinely exceeds temperature criteria during the summer season due to solar radiation. To protect the fishery from the intersecting pressures of high temperature in the epilimnion and low DO in the hypolimnion, the following site-specific assessment methodology is proposed for the Rockport and Echo Reservoir TMDLs:

During periods of thermal stratification, the minimum DO criteria of 4.0 mg/L and maximum temperature of 20^{o}C shall be maintained in a 2-m layer across the reservoir to provide adequate refuge for cold-water game fish. This layer is represented by the metalimnion. These criteria were determined to provide sufficient support for the cold-water game fish beneficial use (3A) designated by the State of Utah for East Canyon Reservoir TMDL approved by EPA in 2010. During periods of complete mixing in the reservoir, all life-stage water quality criteria identified by the State of Utah will be maintained across the reservoir and throughout at least 50% of the water column.

The DO endpoints for Rockport and Echo Reservoirs are consistent with existing Utah water quality criteria and are based on similar endpoints derived for the East Canyon Reservoir TMDL, also in the Upper Weber River watershed. The East Canyon endpoints were developed in collaboration with the Utah Division of Wildlife Resources (DWR) and determined to be protective of the fish species found in the reservoirs. The DEQ and DWR will have an opportunity to review and comment on this approach for these reservoirs prior to completing the final TMDL.

These endpoints apply to normal climatic conditions defined by variable hydrologic conditions across consecutive years, with annual flow within 50% of the 30-year average and current water management regimes. Under conditions of consecutive drought or wet-flow years, the criteria may not be achieved. In addition, periods of extreme spring runoff flows or summer storms may produce conditions that periodically do not attain the criteria.

Reservoir management is another factor that may result in failure to achieve DO concentrations that meet state standards. Releases from Rockport Reservoir occur through the bottom of the reservoir which contains colder water with low DO concentrations. There is also a likelihood of water releases containing high concentrations of dissolved phosphorus because of the anoxic conditions. If Echo Reservoir is already stratified, the releases from Rockport Reservoir may not fully mix and instead may deliver colder water carrying dissolved phosphorus to the lower portions (hypolimnion) of the reservoir. Conversely, reservoir management could help achieve attainment if increased reservoir depths during the critical period create conditions that allow the metalimnion to develop to two meters and at temperatures that fish and aquatic species require.

A-5.2.2 Metalimnetic Oxygen Depletion Rate Targets

The goal of attaining a DO concentration of at least 4 mg/l in the metalimnion is correlated with a target MOD rate, a parameter that has been calculated for current reservoir conditions and can be predicted using the BATHTUB model. The target MOD rate (mg/m^3/day) is calculated by comparing the oxygen concentration below the thermocline at stratification with the target of 4 mg/l to determine how much oxygen can be depleted from the metalimnion. This value is then divided by the total number of days in the stratification season to determine an acceptable target MOD rate. The target MOD rate is therefore related to the starting oxygen concentration in the reservoir and the number of days in the stratification season. A higher initial oxygen concentration and/or a shorter stratification season would result in a higher target MOD rate (Figure A-20). The proposed MOD target for Echo Reservoir and Rockport Reservoir is 36.5 mg/m^3/day based on an assumed initial DO concentration of 9.0 mg/L. If accepted, this target will be used to derive total and dissolved phosphorus targets for the reservoir as well as algal-related targets.

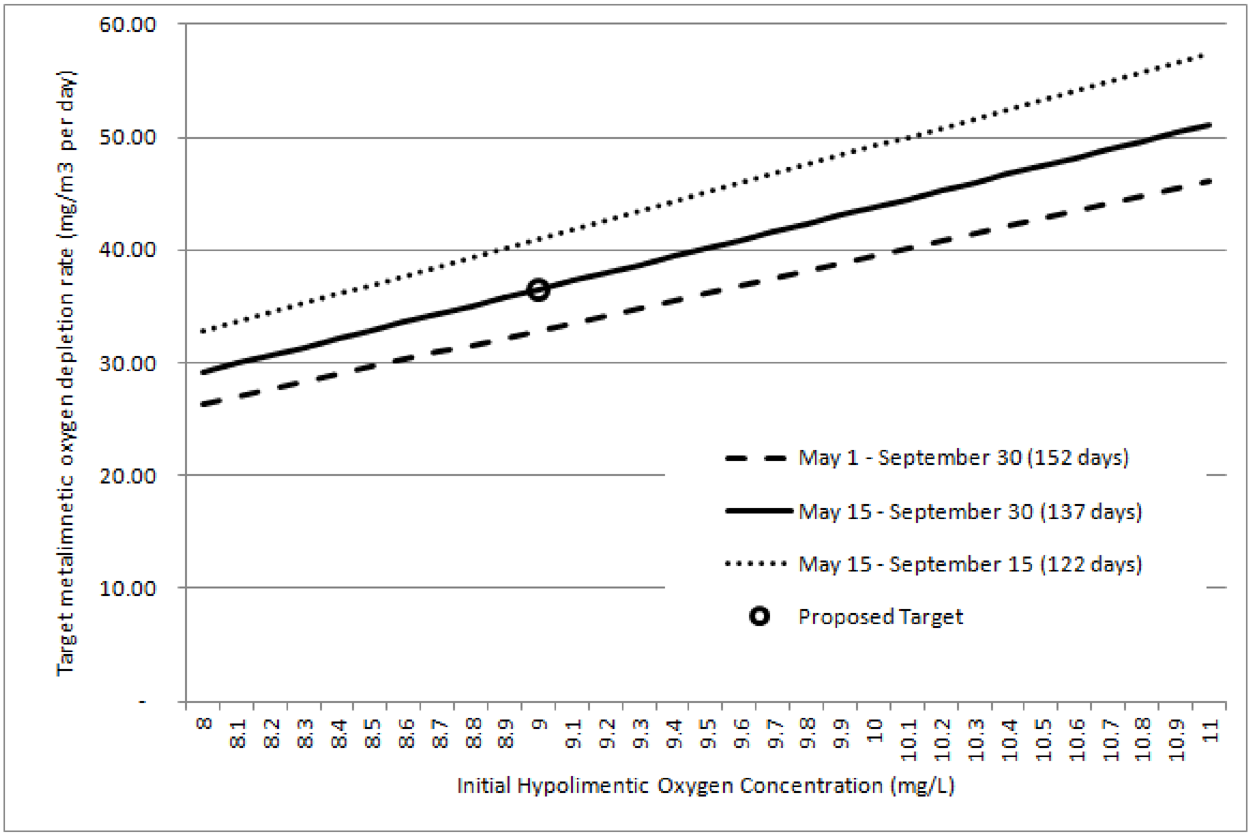

Figure A-20. Relationship between metalimnetic oxygen depletion rate targets and initial hypolimnetic oxygen concentration for three different assumed stratification seasons and proposed target for Rockport Reservoir and Echo Reservoir.

The stratification season for both reservoirs is assumed to be 137 days in length extending from May 15 to September 30. The concentration of DO at the start of stratification, as opposed to during the stratification period, is more difficult to estimate. There are no DO data in early spring, prior to stratification. The earliest spring measurements were taken in Echo Reservoir on May 22, 2007 and on May 29, 2007 for Rockport Reservoir. The average and maximum surface DO concentrations on those dates were 9.1 mg/L and 9.45 mg/L for Echo Reservoir and 7.9 and 8.0 mg/L for Rockport Reservoir, respectively. Although there is very little DO data for either reservoir at stratification, there are more DO data available for the tributaries into and out of the Reservoirs in early spring. These concentrations also provide some perspective on hypolimnetic oxygen depletion rates, especially the concentrations in the Weber River directly downstream of each dam (recognizing that some aeration of the water will occur prior to the monitoring site). A summary of these data is provided in Table A-49 below and indicates the initial concentration of oxygen in the hypolimnion could be as high as 10 mg/L in Echo Reservoir. The use of 9.0 mg/L in deriving the MOD rate target is a conservative assumption for the TMDL analysis. This concentration was further verified by back-calculating a spring oxygen value based on HOD/MOD rates later in the season and dissolved oxygen measurements recorded just after stratification. In 2007, for Echo Reservoir the dissolved oxygen in the metalimnion on May 22, 2007 was 8.75 mg/L. Using the MOD rate of 49.5 mg/m^3/day to calculate backwards to May 15, the starting dissolved oxygen concentration is estimated to have been 9.10 mg/L (the same analysis for 2004 results in a starting dissolved oxygen concentration of 9.05 mg/L; see Table A-50). A similar analysis for Rockport Reservoir in 2007 indicates a starting dissolved oxygen concentration of 9.5 mg/L. This provided additional support for the assumed 9.0 mg/L initial concentration for Echo Reservoir and provides an additional conservative assumption for Rockport Reservoir.

Table A-49. Summary of Early Spring DO Data in Tributaries to and from Rockport Reservoir and Echo Reservoir

	Chalk Creek	Weber River Above Rockport Reservoir	Weber River Below Rockport Reservoir	Weber River Above Echo Reservoir	Weber River Below Echo Reservoir
April					
2004	9.6	10.9	9.8	9.8	12.8
2005	9.5	10.0			
2006	9.8	10.2			
2008	11.0	10.3			
2009	1.8	10.0	9.8	11.4	9.4
Average	**8.3**	**10.3**	**9.8**	**10.6**	**11.1**
May					
2001	10.8	11.1			
2002	8.8	8.9			
2003	8.7	7.9		10.3	
2004	8.9	9.5	10.8	10.6	11.3
2006	15.2	12.0			
2007	11.2	10.6	11.0	12.0	9.2
2009	9.8	9.8	9.1	11.5	9.4
Average	**10.3**	**10.0**	**10.4**	**11.0**	**10.3**

Table A-50. Estimate of initial dissolved oxygen concentrations using profile data and back extrapolation

	2004	2007	2011
Rockport Reservoir			
Calculated MOD Rate (mg/m^3/day)	59.2	50.3	64
Date of first profile	6/14/2004	6/27/2007	6/20/2007
Days after May 15	30	44	36
DO in metalimnion at profile (mg/l)	7.8	7.3	8
Calculated initial DO in metalimnion (mg/l)	9.6	9.5	10.3
Echo Reservoir			
Calculated MOD Rate (mg/m^3/day)	53.8	49.5	58.0
Date of first profile	6/15/2004	5/22/2007	6/8/2011

Table A-50. Estimate of initial dissolved oxygen concentrations using profile data and back extrapolation

	2004	2007	2011
Days after May 15	31	7	24
DO in metalimnion at profile (mg/l)	7.4	8.8	8.6
Calculated initial DO in metalimnion (mg/l)	9.1	9.1	9.9

A-5.3 Nutrient Reduction Scenarios

Attainment of the DO endpoints under various nutrient loading scenarios can be derived by comparing the MOD rate predicted using BATHTUB to the target MOD rate. All nutrient loading scenarios represent equal reductions in nitrogen and phosphorus to the reservoirs. Multiple nutrient reduction scenarios were run using the calibrated BATHTUB models specific to the three conditions (dry, average, and wet) including the minimum nutrient reduction required to attain the proposed MOD target. The nutrient reductions required range from 32% to 35% for the average condition and 48% for the wet condition in Rockport Reservoir. The nutrient reductions needed range from 34 to 40% for the average and dry conditions to 44% for the wet condition for Echo Reservoir. (Figure A-21).

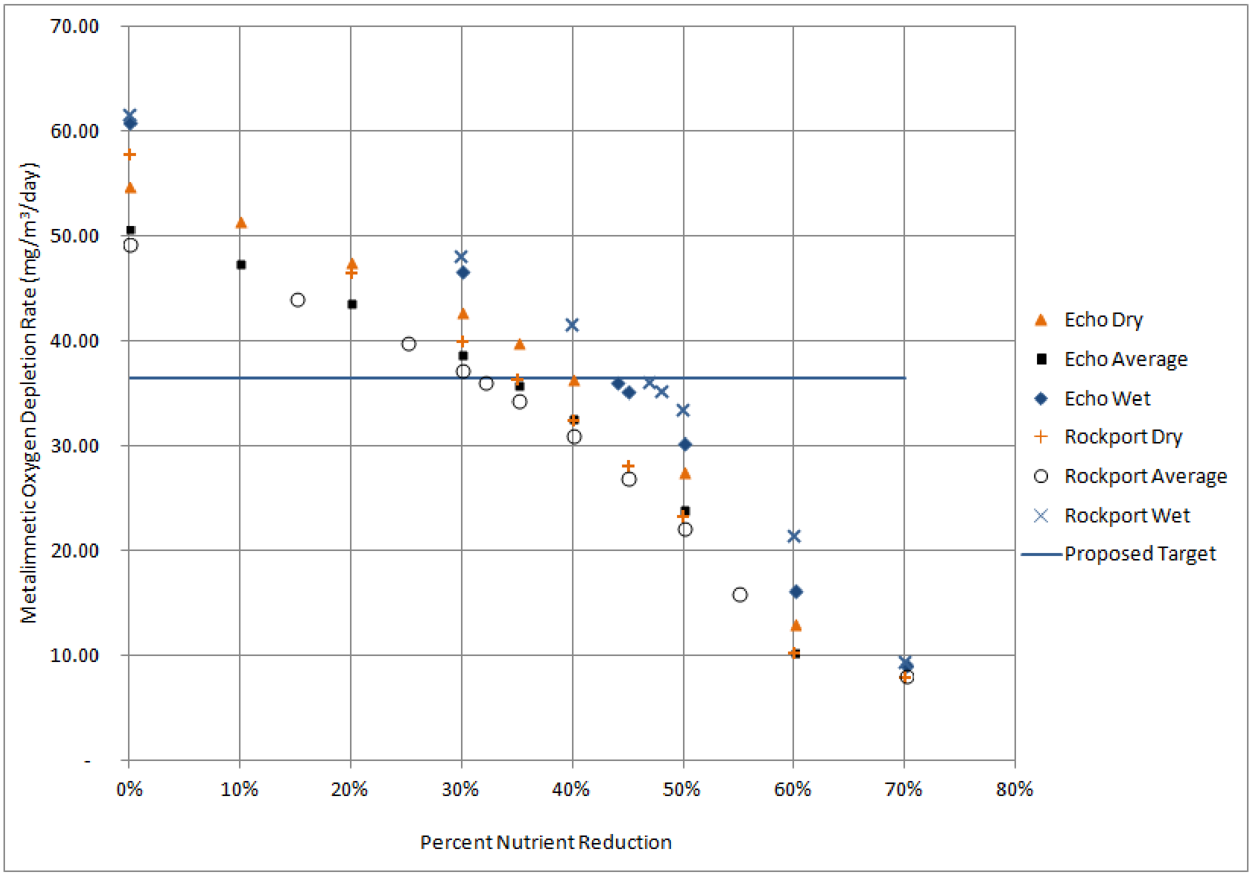

Figure A-21. Predicted MOD rates under various nutrient reductions scenarios.

A-5.4 Predicted Reservoir Water Quality

Average seasonal water quality in the reservoirs, based on the nutrient reduction scenarios for each condition that would achieve the targeted metalimnetic oxygen depletion rate, are presented in Tables A-51 and A-52 below.

Table A-51. Predicted Rockport Reservoir Water Quality under Proposed Nutrient Load Reductions

	2004	2007	2011
Current			
Total Phosphorus (μg/L)	37.0	16.8	36
Total Nitrogen (μg/L)	369	382	348
Chlorophyll-a (μg/L)	2.2	No data	2.1
Organic Nitrogen (μg/L)	481.2	238.2	251.0
Orthophosphate (μg/L)	32.1	16.3	27
Nutrient reduction to reach proposed MOD target	35%	32%	47%
Target Water Quality			

Table A-51. Predicted Rockport Reservoir Water Quality under Proposed Nutrient Load Reductions

	2004	**2007**	**2011**
Total Phosphorus (µg/L)	27.1	14.7	19.3
Total Nitrogen (µg/L)	267.6	268.9	223.3
Chlorophyll-a (µg/L)	3.2	3.7	2.3
Secchi depth (m)	6.2	5.8	7.2
Organic Nitrogen (µg/L)	236.2	238.5	216.2
Orthophosphate (µg/L)	3.5	4.3	1.9

Table A-52. Predicted Echo Reservoir Water Quality under Proposed Nutrient Load Reductions

	2004	2007	2011
Current			
Total Phosphorus (µg/L)	18.4	18.3	35.9
Total Nitrogen (µg/L)	657.1	413.5	714.9
Chlorophyll-a (µg/L)	1.6	3.5	4.3
Organic Nitrogen (µg/L)	526.5	319.4	572.8
Orthophosphate (µg/L)	13.5	13.0	34.5
Nutrient reduction to reach proposed MOD target	40%	34%	44%
Target Water Quality			
Total Phosphorus (µg/L)	13.5	18.7	21.9
Total Nitrogen (µg/L)	230.7	269.9	237.8
Chlorophyll-a (µg/L)	2.3	3.7	2.9
Secchi depth (m)	7.2	5.8	6.5
Organic Nitrogen (µg/L)	215.9	247	229.9
Orthophosphate (µg/L)	1.9	4.3	3.0

A-5.5 Uncertainty and Variability

Sources of uncertainty and variability associated with all models including SWAT and BATHTUB can be generalized into three categories: data representativeness or the uncertainty and variability for data used for calibration; uncertainty and variability in the values used to characterize parameters; and uncertainty in the understanding of the processes occurring and the equations and parameters used in the model to simulate processes. These issues are discussed with respect to the Rockport Reservoir and Echo Reservoir TMDLs in the following sections.

A-5.6 Data Representativeness

While much of the data available for the Rockport and Echo Reservoir TMDL analysis are robust and comprehensive, there are some deficiencies in data representativeness that contribute to the uncertainty associated with the modeling output. These data deficiencies are summarized in Table A-51 with a summary of how the deficiency has been handled in the current modeling analysis. While these deficiencies do not prevent development of the TMDL, they represent important aspects of uncertainty and should be used to frame additional monitoring efforts in the future.

Table A-53. Identified Data Gaps for Rockport and Echo Reservoir TMDLs

Data Deficiency	Importance	Procedure Used to Address the Data Deficiency
High elevation climate data	The SWAT model generates climate data based on elevation bands in the watershed using available climate data from multiple climate stations. Although the climatic data generated by SWAT based on valley climate includes algorithms to account for elevational changes, there is significant uncertainty at the daily timescale of the predicted high elevation climate. This uncertainty prevented better calibration of hydrology.	Snow parameters and coefficients related to high elevation climate predictions were modified to best match the hydrologic data. Remaining uncertainty was somewhat mitigated through calibration of nutrient loads at a seasonal time scale. In this way, while the timing of load delivery to the reservoirs is not perfect, the seasonal loads to the reservoirs are reasonable.
Water quality data collected during storms	Loads calculated for average and dry conditions using measured water quality and flow data were unrealistically low for Echo Reservoir, based on known loads from Rockport Reservoir releases and point source discharges. Further examination of data collected in the summer in Chalk Creek and the Weber River indicate that only one sample was collected during a storm event since 2002. The bulk of the summer nutrient load is likely to occur during storm events when erosion occurs in the watershed and stream channels. Samples collected during storms in summer 2012 in the Chalk Creek watershed demonstrate that nutrient concentrations are several times higher during storms than base flow water quality. This results in a “missing load” in the calculated seasonal loads to the reservoirs.	Loads calculated using measured flows and water quality during spring runoff are more representative of actual loads. The SWAT model for the Echo Reservoir watershed was calibrated to the measured spring runoff load. The summer loads were then predicted using the calibrated model. This approach will also be taken for Rockport Reservoir watershed and total loads to Rockport Reservoir will be revised accordingly for the final TMDL.
Initial soil nutrient concentrations	The SWAT model is relatively sensitive to initial soil nutrient concentrations, both organic and dissolved forms. No soil nutrient data is available for the watersheds.	Soil nutrient values were initially generated by SWAT based on the organic components of the soil, data available in STATSGO. These values were modified for phosphorus based on the concentration of phosphorus in the underlying geology. This provided good differentiation of soil phosphorus conditions between soils. Soil nutrient concentrations were then used as a primary calibration tool for nutrient calibration of loads to the reservoirs.
Reservoir DO data from early spring	The concentration of oxygen in the hypolimnion at stratification is a critical assumption in calculating an acceptable oxygen depletion rate for each reservoir. No hypolimnetic oxygen data is available for either reservoir in April or early May.	Dissolved oxygen data from reservoir surfaces in late May and in the Weber River below each reservoir in April and May were used to develop an assumed initial DO concentration for the reservoirs; 9.0 mg/L for Rockport Reservoir and 10.0 mg/L for Echo Reservoir.

Table A-53. Identified Data Gaps for Rockport and Echo Reservoir TMDLs

Data Deficiency	Importance	Procedure Used to Address the Data Deficiency
Organic matter loading to reservoirs	The BATHTUB models were calibrated to oxygen depletion rates driven by algal growth and nutrients in the reservoirs. However, organic matter loading to the hypolimnion from the watersheds could also contribute to oxygen depletion. There are very few data related to organic matter loading from the Weber River to the reservoirs.	Contribution to oxygen depletion from organic matter is not accounted for in the analysis. This is a protective assumption, in that all of the improvement in oxygen depletion will be achieved through nutrient reductions. Any BMPs implemented to reduce nutrients in the watershed would likely also reduce organic matter loading.

A-5.6.1 Model Parameterization

The parameters used in developing models and the values chosen for those parameters can affect model results and contribute to uncertainty. Model parameters should be assigned values that are representative of conditions present during the time period modeled. The SWAT parameters remained within the SWAT default ranges and were based on information generated from raw data or provided by local watershed stakeholders including land management agencies. Some parameters such as snow, routing, and groundwater parameters were used to calibrate the model and therefore the values used for these parameters were those that created a best fit for either the simulated hydrology or the simulated nutrient loads. Other parameter values, in particular the values used to describe agricultural and irrigation operations, were generalized based on available data and input from agencies. The values used for these parameters have more uncertainty associated with them because they are based on observations or numbers for a single year that are attributed to all years included in the simulation. In addition, some model parameters required values for which there was data for some parameters, but not all. For example, nitrogen and phosphorus data had to be partitioned into various components such as organic nitrogen or mineral phosphorus for input files that describe point sources for SWAT. The initial soil nutrient conditions also are a source of uncertainty for two reasons: agricultural inputs and high rock phosphorus concentrations affect nutrient levels, particularly phosphorus, in the soil; and there are no known standard methods to estimate the contributions from underlying rock over time to soil nutrient concentrations. Therefore, these values were adjusted as part of calibration. BATHTUB parameters were based on measured data or estimated from existing data such as bathymetry. Uncertainty will exist in the volumes calculated from bathymetry because of annual sediment filling that slowly reduces the total reservoir volume over time. Uncertainty also exists in the length of stratification season and the parameters used to predict the MOD rates. However, the values used are based on measurements at these reservoirs for the specific year modeled, which reduces the uncertainty and addresses variability between the reservoirs and years. Uncertainty in model parameterization also exists for the BATHTUB model because values for all inputs were not equally available for both reservoirs and segments.

A-5.6.2 Physical and Chemical Processes

Our understanding of the physical and chemical processes that are simulated in the model is somewhat limited, thereby increasing uncertainty in the model results. In both the SWAT and BATHTUB models, users have the option to choose different equations for the model to use, for example, in channel sediment generation or predicting MOD rates. There is some uncertainty associated with the equation itself and how well it simulates specific conditions and whether the equation was developed for conditions within the project area. For example, in SWAT, the Penman-Monteith Equation may provide more accurate estimates of potential evapotranspiration, but relies heavily on weather statistics. The model also offers four equations for estimating channel erosion, each having been developed for specific conditions. With

BATHTUB, different combinations of empirical sub-models better represent the conditions of each reservoir during a dry, wet, and average year. Using different equations, sub-models, or combinations of either create uncertainty because they generate slightly different results. Throughout the analysis, best professional judgment was used to select the most appropriate model equation or submodel for each process.

A-5.6.3 Reservoir Dynamics

The target water quality for nutrients, based on the BATHTUB modeling, results in very low nutrient concentrations in the surface of both reservoirs, especially Echo Reservoir, and may not be attainable. It should be further noted that the average seasonal phosphorus concentrations in some years in which DO impairments have been observed are already below the threshold value (0.025 mg/L) identified by the State of Utah to indicate a nutrient concern. This points to the possibility of another driver of oxygen depletion, other than algal growth responding to nutrients.

One possibility is that organic matter loading to the hypolimnion from the watersheds could be contributing to oxygen depletion. Organic matter serves as a food source for heterotrophs, which respire, die, and decompose. These reactions are aerobic and use oxygen if available, thereby contributing to oxygen depletion in the reservoir water column and increasing sediment oxygen demand at the bottom of the reservoir. Thermal stratification may confine these effects to the hypolimnion during the spring-summer season. The water temperature of the Weber River is lower than the surface temperature of the reservoirs in the summer. Accordingly, much of the water delivered to the reservoirs in the summer may bypass the surface and sink to the hypolimnion directly. While the effect of this phenomenon on nutrient loads to the epilimnion has been accounted for through calibration of nutrient sedimentation rates in the reservoir, the BATHTUB model does not account for additional oxygen depletion associated with organic matter. Further, there are very few data related to organic matter loading from the Weber River to the reservoirs that could be used in any analysis of this potential driver. Thus, contribution to oxygen depletion from organic matter is not accounted for in the current analysis. This is a protective assumption, in that all of the improvement in oxygen depletion will be achieved through nutrient reductions. Any BMPs implemented to reduce nutrients in the watershed would likely also reduce organic matter loading as both nutrient and organic matter transport are associated with soil erosion and sediment transport from the watershed.